FAO ENVIRONMENT PAPER 1

natural resources and the human environment for food and agriculture

FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS ROME

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Rome, 1980

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FOREWORD

At the beginning of the present century the world population was a little more than 1 500 million; but it rose to 2 500 million in 1950 and 4 000 million in 1975. By the year 2000 it is expected to reach about 6 300 million, of which about two thirds will be in the developing countries.

To feed these people and to improve their quality of life, it will be necessary in the next 25 years to more than double the production from agriculture, fisheries and forestry. This colossal task will involve drawing heavily on the renewable natural resources which are of basic importance for sustaining and increasing food and agricultural production such as soil, water, animals, fish, plants, grasslands and forests.

The above unprecedented rise in population has already placed considerable pressure on natural resources and has in many cases led to their degradation and depletion. In the future this pressure will become even greater.

Taking these factors into consideration, FAO, through its Inter-Departmental Working Group on Natural Resources and the Human Environment, has prepared this report on Natural Resources and the Human Environment for Food and Agriculture. It is rewarding for me to recall here that all the FAO Regional Conferences held in 1978 commended FAO for the preparation of this document. For the first time, an attempt was made not only to review the issues and challenges to be faced in managing these finite resources to meet the increased demand for agricultural production, but also to assess the impact of the unprecedented increase in population, and the associated socio-economic changes, on the state of those resources and the environment generally.

The Regional Conferences also stressed that the wise use, conservation and management of natural resources as well as concern for the maintenance of the ecological balance should be at the core of any rural development programme aimed at increasing agricultural production and improving the quality of life of the rural population.

This initial assessment does not pretend to be exhaustive. It is only a first approach and will need to be progressively improved and refined. Although global in scope, it uses illustrations and draws on specific data from a number of countries. It also provides a framework for other similar studies at regional, national and village levels.

This publication is the first in the new technical series on natural resources and the human environment.

EDOUARD SAOUMA
DIRECTOR-GENERAL

This One
PBCW-SSL-57KS

This report is a first attempt to interrelate at global level population pressure, natural resources use and management, with particular reference to increased food and agricultural demand and the ensuing environmental issues. The report is the result of teamwork carried out by the Inter-Departmental Working Group on Natural Resources and the Human Environment, and was first published as Chapter 3 of The state of food and agriculture 1977.

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INTRODUCTION

Man's demands on the natural resources that sustain his existence have increased enormously with the unprecedented rise in his numbers that has occurred in modern times. Two centuries ago the world population was probably still less than 1,000 million, and by the beginning of the present century it was only a little more than 1,500 million. But it rose to 2,500 million in 1950 and 4,000 million in 1975. Although the population is generally expected to stabilize some time towards the end of the next century, further large increases are inevitable in the meantime. Looking only as far ahead as the end of this century, the latest United Nations projections indicate a world population somewhere between 5,800 and 6,600 million, with the most probable figure around 6,300 million.[1]

The past population growth has already placed considerable pressure on natural resources, and has in many cases led to their degradation and depletion. In the future this pressure will become even greater. Merely to sustain the likely population of 6,300 million in the year 2000 at current levels of consumption would entail a further increase of almost 60% in agricultural, fisheries and forestry production in the quarter of a century from 1975. Allowing for the expected rise in incomes and effective demand might raise this figure to at least 80%.[2]

But the demands on natural resources are likely to rise even more rapidly than is indicated by such figures. More than 90% of the population increase that is expected by the year 2000 would be in the developing countries, so that they would by then account for almost 80% of the world total.[3] A very large number of people in these countries still live in abject poverty and are unable to obtain their nutritional and other basic needs. If their basic needs are to be met by means of income redistribution and other measures, and if the income gap between the developed and developing countries is to be reduced in the spirit of the Declaration and Programme of Action on the Establishment of a New International Economic Order, agricultural production in the developing countries will have to be increased at an unprecedented rate.

Even the effective demand for food in the market in these countries is rising by as much as 3.6% a year[4]. Meeting the basic needs of their poorest people by the end of the century would entail a still faster increase in their production. The International Development Strategy adopted for the Second United Nations Development Decade, covering the

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[1] United Nations, World Population Prospects as Assessed in 1973, Population Studies, No. 60, New York, 1977, p. 14.

[2] FAO's projections of the future demand for food and agricultural products are at present being revised and updated to cover the 1990s in the longer-term perspective of the whole period up to the end of the century. A global perspective study, entitled Agriculture: Towards 2000, is now in preparation. In the meantime, the latest FAO projections of the world demand for food from 1969-71 to 1985 indicate an average annual increase of 2.4% (United Nations World Food Conference, Assessment of the World Food Situation, Present and Future, E/CONF.65/3, Rome, 1974, p. 79).

[3] United Nations, op. cit., p. 15.

[4] United Nations World Food Conference, op. cit., p. 15.

1970s, set the target of a 4% average annual increase in the agricultural production of the developing countries. This target was reaffirmed, in respect of food production, by the World Food Conference in November 1974. Even this rate of growth would probably not suffice to meet the basic needs of the poor by the end of the century, but it would already imply that the food production of the developing countries should be doubled in the next 18 years, in comparison with the period of slightly less than 25 years taken for the last doubling.

The past damage to natural resources and the greatly increased pressure on them that is to be expected in the future, especially in the developing countries, make it urgent to carry out an assessment of these resources. The productive capacities of most of the natural resources that are used for agricultural production depend on delicate physical and biological balances that man does not yet fully understand and cannot fully control. The ecological equilibrium appears to be less stable in the tropics, where most of the developing countries are to be found, than in the temperate zone. Man's capability of disturbing this equilibrium has vastly increased and, whenever a resource is used beyond its productive capacity, this results in degradation and depletion, often beyond the possibility of recovery for many generations to come. At the same time, modern agriculture is developing approaches and methods that make production possible on a sustained basis, through a better understanding of the productive capacity of natural resources under various ecosystems. It is therefore necessary to identify these approaches and methods more clearly, and to adapt them to the different socio-economic conditions of local environments.

The Seventeenth Session of the FAO Conference discussed these problems, and concluded that "the major environmental problems facing agriculture, forestry and fisheries were not only the avoidance of environmental pollution but the ensuring, in the development process, of the maintenance of the productive capacity of the basic natural resources for food and agriculture through rational management and conservation measures". It recognized that "agricultural development and world food security depended on the careful husbandry of living resources, on their biological laws and ecological balances as well as on the adjustments of production, supply and reserves to demands". It therefore endorsed the Director-General's proposal "to make periodic assessment of 'the State of Natural Resources and Environment' as an essential complement to the existing yearly report on the State of Food and Agriculture in the field of production and economics."5/

This chapter has been prepared as the first such assessment. It is a preliminary benchmark survey of the state of the natural resources of principal importance for agricultural production and development, and of some of the more critical problems that have arisen from man's use of these resources. Since it is aimed at a wide audience, it attempts to highlight the crucial issues, without going into too much detail on technical and management aspects. Its preparation has been made difficult by the lack of adequate basic data. For many countries data on the natural resources for food and agriculture are either completely lacking or, at best, incomplete and heterogeneous. This first global assessment therefore cannot pretend to be exhaustive, and will have to be revised and updated as improved data become available.

The main objectives of the chapter are threefold: first, to provide a broad overview of the complexity, vastness and importance of the problems of natural resource management and conservation in relation to food and agricultural production; second, to draw attention to the possibilities and limitations of the productive capacity of certain key natural resources, in relation to other resources and to the environment, for the satisfaction of man's present and future requirements on a sustained basis; and, third, to

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5/ FAO, Report of the Conference of FAO, Seventeenth Session, Rome, 10-29 November 1973, C 73/REP, Rome, 1973, p. 57.

identify critical environmental issues deriving from the pressure put on natural resources, particularly in developing countries, in order to satisfy the rapidly increasing demand for food and agricultural products.

The first and main part of the chapter consists of a global overview of the state of the principal natural resources for food and agricultural production, and of related environmental issues. The remainder of the chapter is necessarily much more selective. Four specific problems of the environmental impact of the intensification of agricultural production are briefly discussed: those arising from fertilizer use, pest control, pollution by forest industries, and the contamination of food and feed. Some environmental problems are to a great extent specific to certain ecological zones, and of these three are selected for discussion: shifting cultivation in the sub-humid and humid tropical zones, desertification, and land utilization problems in highland areas. After a brief review of some of the legislative aspects of environmental problems, the chapter attempts to draw some general conclusions on the state of natural resources, the different environmental problems of developed and developing countries, and some of the requirements for the better assessment and management of natural resources.

THE STATE OF NATURAL RESOURCES

The following global overview of the state of natural resources covers soil, water, grazing land and forage, forests, wildlife, fisheries, and genetic resources. Although atmospheric resources such as air and climate are also of major importance for agriculture, they are not dealt with separately here in view of the lack of knowledge of man's influence on them. Energy resources and their use in agriculture were examined in the 1976 issue of The State of Food and Agriculture.[6]

Each of the main natural resources is of necessity treated separately, although the interrelations between the different resources are brought out as far as possible. In each case an account is given of the principal problems arising from man's activities in using the resource.

SOIL RESOURCES

The appraisal of soil resources on a global basis has been attempted from the beginning of the century, and various estimates have been made of the extent and distribution of the world's potentially arable soils. A recent study noted that the world's arable land area could be increased from 1,400 to 3,200 million hectares, and that over 50% of the unused potential was in tropical areas.[7]

Estimates of this kind have been handicapped by inadequate data for some regions and by the lack of a uniform approach, which has made it difficult to compare data from different parts of the world. Furthermore, overall estimates of "arable land" which do not specify the type of land use envisaged provide only a very rough indication of the potential of land resources. A unified approach for obtaining a more accurate inventory and appraisal of the world's soil resources has recently been developed in the framework of the FAO/UNESCO Soil Map of the World[8]. By interpreting this information in terms of major limitations for agricultural use, a general indication can be given of the distribution of soil resources and their potential for food and agricultural production.[9]

6/ FAO, The State of Food and Agriculture 1976, Rome, 1977, p. 79-111.

7/ C.E. Kellogg and A.C. Orvedal, Potentially Arable Soils of the World and Critical Measures for their Use, United States Department of Agriculture, 1977.

8/ FAO/UNESCO, Soil Map of the World, Vol. 1, Paris, 1964.

9/ R. Dudal, Inventory of major soils of the world with special reference to mineral stress, Proceedings of Workshop on Adaptations of Plants to Mineral Stress in Problem Soils, ARS, Cornell University, AID, Washington, D.C., 1976.

FAO is now compiling data on the extent of the land variously suited to the rain-fed production of twelve major crops at two levels of inputs (approximating to subsistence and commercial farming). The study takes into account both climatic and soil conditions, and the results are to be presented by agro-ecological zones. In this way the food production potential of different regions will be determined. In the assessment, the principles of the FAO Framework for Land Evaluation are being applied, including the concept that suitability refers to use on a sustained basis and without risk of environmental degradation. Any comprehensive land use planning through land suitability assessment must take full account of the interrelations between the desired technical and socio-economic goals and the physical and biological components of the environment.

On a global basis, the main limitations to the use of the world's soil resources for agricultural production are drought, mineral stress, shallow depth, water excess, and permafrost (Table 3-1). Only about 11% of the world's soils offer no serious limitations to agriculture. Europe, Central America and North America have the highest proportion of soils with no serious limitations. North and Central Asia, South America and Australasia have the lowest proportions. Drought is the dominant limitation not only on a world basis but also in Central America, Africa, South Asia, and Australasia.

The uneven geographic distribution of soil resources does not correspond to the equally uneven distribution of population. There is thus an imbalance between land potential and food and agricultural requirements in various regions of the world. The uneven distribution of soil resources may be illustrated by comparing the endowments of South America and Africa.

The dominant feature in South America is the high proportion of soils with low fertility status. Almost 50% of the continent, centred on the Amazon basin and the central uplands, is occupied by such soils. Soils under semi-arid climates occupy approximately 17% of the continent, covering large parts of the western and southern uplands, the lowlands and mountain deserts along the west coast, and the Andean Altiplano. Steep lands, with limited agricultural potential, make up about 11% of the continent.

In Africa, 44% of the area is occupied by deserts or soils under arid and semi-arid climates. Soils with low fertility status occupy a further 18% of the area. The soils of the savanna zones suffer from unfavourable physical properties and can be subject to severe erosion. Large areas with iron-stone crusts occurring at various depths in the soil are particularly threatened by erosion, since the removal of surface layers irreversibly lessens rooting depth.

Table 3-1. World soil resources and their major limitations for agriculture

	Drought	Mineral stress[1/]	Shallow depth	Water excess	Permafrost	No serious limitations
	.... % of total land area					
North America	20	22	10	10	16	22
Central America	32	16	17	10	-	25
South America	17	47	11	10	-	15
Europe	8	33	12	8	3	36
Africa	44	18	13	9	-	16
South Asia	43	5	23	11	-	18
North and Central Asia	17	9	38	13	13	10
Southeast Asia	2	59	6	19	-	14
Australasia	55	6	8	16	-	15
WORLD	28	23	22	10	6	11

Source: Data compiled from FAO/UNESCO Soil Map of the World, Paris, 1964-74.

[1/] Nutritional deficiencies or toxicities related to chemical composition or mode of origin.

The available evidence indicates that globally soil resources are sufficient to meet a large expansion in the current world demand for food and agricultural products. The major constraint resides in the uneven geographic distribution of these resources with respect to population density and the level of technology applied in their use. This creates imbalances between the land available for agriculture and the food requirements of a country or region, with the result that in certain areas the expansion of arable land into marginal areas may cause severe degradation and even loss of soil resources.

Soil degradation problems

Soil degradation refers to the deterioration or total loss of the productive capacity of the soil for present and future use. It has many causes, but those of most immediate concern are erosion, salinization and waterlogging, and chemical degradation.

Erosion is the washing or blowing away of surface soil. This phenomenon may take place without man's influence, but it is often accelerated when his activities cause the disappearance of the protective cover of natural vegetation. Soil may be washed or blown away faster than it can regenerate, resulting in a net soil loss. The degree to which erosion takes place is influenced by a combination of factors, the most important being climate, the slope of the land, vegetation cover, the nature of the soil, and cultivation practices. Erosion hazards severely limit the range of uses to which the land may be put.

A rough idea of the degree and distribution of soil erosion in the world may be obtained from estimates of the suspended sediment loads of major rivers.10/ It appears that the most susceptible areas are the lands receiving medium to high rainfall with latitudes approximately between 42° north and 42° south. In tropical areas the danger of soil erosion from run-off and rain is negligible wherever dense evergreen forest is present but, as soon as it is removed, especially on slopes, serious erosion may take place. The hazard of soil erosion decreases in the temperate regions at higher latitudes where rainfall is gentler and more evenly spread throughout the year.

Table 3-2 lists the world's major rivers in terms of their mean annual yield of suspended sediment. Erosion intensity can be assessed by comparing the area of the basin with the total sediment load. The International Commission on Erosion and Sedimentation is compiling a world map on the basis of such data.

Whilst heavier sediment loads are associated with humid tropical zones, there is also a positive correlation with the relative proximity of mountains to the sea. This is especially so in Southeast Asia, Europe, South America, and generally at latitudes around 20° north.

A major problem associated with erosion and sedimentation is that of siltation, which can result in the silting up of reservoirs and streams and in the frequent clogging of irrigation channels. It is estimated that more than 1,000 million m^3 of sediment are deposited each year in the major reservoirs of the United States alone.11/ The cost of sediment removal, the dredging of streams, the purification of water supplies and the reconstitution of irrigation systems is enormous.

Wind erosion can be a problem in all dry and semi-arid areas, as well as in areas of sloping or flat lands with seasonal rainfall. The conditions which favour wind erosion are dry loose soil with little or no vegetative cover, a relatively smooth surface, and a

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10/ F. Fournier, Climat et érosion: la relation entre l'érosion du sol par l'eau et les précipitations atmosphériques, Paris, 1960.

11/ N. Holeman, The sediment yield of major rivers of the world, Water Resources Research, 4, 1968, p. 737-747.

Table 3-2. Major rivers of the world ranked by sediment yield

River	Drainage basin	Average annual suspended load	
	thousand km^2	million metric tons	metric tons/km^2
Yellow	673	1,887	2,804
Ganges	956	1,451	1,518
Brahmaputra	666	726	1,090
Yangtze	1,942	499	257
Indus	969	435	449
Ching	57	408	7,158
Amazon	5,776	363	63
Mississippi	3,222	312	97
Irrawaddy	430	299	695
Missouri	1,370	218	159
Lo	26	190	7,308
Kosi	62	172	2,774
Mekong	795	170	214
Colorado	637	135	212
Red	119	130	1,092
Nile	2,978	111	37

Source: N. Holeman, The sediment yield of major rivers of the world, Water Resources Research, 4, 1968, p. 737-747.

wind of sufficient velocity. In the semi-arid and sub-humid regions the expansion of livestock numbers and overgrazing lead to the breakdown of the traditional pastoral systems, with the result that soils are stripped of their vegetative cover and become subject to severe blowing.

Salinization is the accumulation of salts to the extent that they have a deleterious effect on soil productivity and crop yields. Alkalinization refers to a high saturation of the soil with sodium. The main factors affecting salinization are the aridity of the climate, geomorphology, topography, hydrology, the physical properties of the soil, and agricultural management practices.

Salt affected soils are found in every continent (Table 3-3), and it is estimated that they total close to 7% of the land area of the world. In Europe only about 51 million hectares of saline soils are reported, but the potentially salt affected areas are considerably larger. The problem is very extensive in Australasia, with 357 million hectares affected, and also in the U.S.S.R., with close to 200 million hectares. Salinization is also a major problem in the Near East, although its extent in quantitative terms is not known in all the countries of the region.

Chemical degradation may occur if the nutrients in the soil are not replenished to maintain soil fertility. Particularly in the humid tropics, the climate is very conducive to the leaching and depletion of soil nutrients. As was shown in Table 3-1, while 23% of the world's soils suffer from mineral stress, the proportion is as high as 59% in South-east Asia and 47% in South America.

The traditional practice of shifting cultivation, aiming at the replenishment of soil fertility through long fallows (10 to 25 years, depending on the nature of the soil), has for a long time been the land use best adapted to the conditions prevailing in the humid tropics. When population growth necessitates more intensive land use, however, a reduction in the length of the fallows may result in rapid chemical degradation, and a drop in yields. Shifting cultivation is discussed in more detail in a later part of this chapter.

Table 3-3. World distribution of salt affected soils

Region	Area	
	thousand ha	% of total land area
North America	15,755	0.9
Central America	1,965	0.7
South America	129,163	7.6
Europe	50,804	4.6
Africa	98,521	3.5
South Asia	85,108	7.9
North and Central Asia	211,686	7.2
Southeast Asia	19,983	5.9
Australasia	357,330	42.3

Source: Data compiled from FAO/UNESCO, Soil Map of the World, op. cit.

While the problem of soil degradation is of great magnitude, no comprehensive appraisal has yet been made. A global assessment of both actual and potential soil degradation is now being undertaken by FAO, with the support of the United Nations Environment Programme (UNEP).

WATER RESOURCES

The water available to man is only a small fraction of the total estimated water resources of the world ($1.4 \times 10^9 km^3$), since 95% is saline, 4% is frozen and only the remaining 1% is in a fresh liquid state. Of this small percentage, almost 98% is groundwater and 2% is surface water.[12]

As water is a renewable resource and is needed in continuous supply by man, the concept of its annual flow through the hydrological cycle is important. Estimates of the annual volumes of water moving through the different parts of the hydrological cycle are shown in Table 3-4. Although the circulation of groundwater comprises only 0.4% of the world's total water, it is still a vast quantity.

Table 3-4. Annual global flows of water (hydrological cycle)

	km^3	% of total precipitation
Total precipitation	577,000	100
Precipitation over land	118,900	20.6
Evaporation from land	72,000	12.5
Run-off from land to oceans	46,900	8.1
Surface water	44,700	7.7
Groundwater	2,200	0.4

Source: M. Holy, op. cit.

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[12] M. Holy, Water and the Environment, Irrigation and Drainage Paper No. 8, FAO, Rome, 1971.

The paradox of the abundance of annual supplies of fresh water on the one hand and water shortages on the other lies in the variability of their distribution in space and time. The amount of fresh water available is meaningless unless it is related to where and when it is needed by man and by nature itself. Some regions of the world have perennial surpluses and others shortages. Africa has, on the average, an excess of precipitation over evaporation, but there is a marked difference between the Sahelian zone and the more tropical regions. This spatial variation also occurs at the country level and within river basins. An idea of its magnitude at the country level may be obtained from Table 3-5. The percentage of potential evapotranspiration covered by rainfall varies from 274% at Sao Gabriel, Brazil, to as little as 1% at Antofagasta, Chile. The amount of water available for rainfed crops is indicated by the figures exceeding 100%.

Table 3-5. Annual rainfall and potential evapotranspiration for selected stations in Africa and South America

	Annual rainfall	Annual potential evapotranspiration	Amount of potential evapotranspiration covered by rainfall
	........mm..........		%
AFRICA			
Yangambi, Zaire	1,710	1,130	151
Brazzaville, Congo	1,450	1,360	107
Kaduna, Nigeria	1,250	2,050	60
Port Amelia, Mozambique	800	1,430	55
Ouagadougou, Upper Volta	930	2,550	36
El Fasher, Sudan	300	3,210	9
Villa Cisneros, Spanish Sahara	70	920	8
Tamanrasset, Algeria	30	2,310	2
SOUTH AMERICA			
Sao Gabriel, Brazil	2,956	1,078	274
Calabozo, Venezuela	1,280	960	133
Cuenca, Ecuador	705	820	86
Uyani, Bolivia	190	1,160	16
Antofagasta, Chile	10	590	1

Source: United Nations, 'The Demand for Water,' op. cit.

Added to variability in space is variability in time, which can be either seasonal within the year, or a year-to-year variation. In monsoon regions the average annual precipitation is about 1,800 mm, but 80% of it is concentrated in a five-month period, with widespread flooding often alternating with crop failures owing to water shortages during the dry season. The year-to-year variation also has a major impact, especially in the semi-arid tropics, where the mean annual rainfall is 600-900 mm but is characterized by a high degree of annual unreliability. Under these conditions, farming becomes a risky operation and the area may gradually deteriorate. An instability index based on crop yield data shows that in humid temperate regions annual crop yields vary by an average of 8%, but in certain semi-arid areas this variability can be as high as 40%.13/

13/ United Nations, The Demand for Water, Natural Resources, Water Series No. 3, New York, 1976.

Where it is available, surface water (lakes, rivers, etc.) is extensively used for agriculture and other needs. It is supplemented, to varying degrees, by groundwater. The ratio of groundwater use to total water use depends, above all, on the availability of other water resources. For this reason groundwater resources assume greater importance in the more arid regions. Table 3-6 compares water use between some of the more arid and more humid areas of the United States. In the more arid areas, where the proportion of groundwater use is higher than elsewhere, irrigation is often a major factor in this regard.

Table 3-6. Comparison of groundwater use in the United States between more arid and more humid states

State	Public supplies	Rural	Irrigation	Industrial	Total ground water use	Ratio of groundwater use to total water use
	....	million gallons per day	....			... % ...
MORE ARID STATES						
Arizona	110	10	4,700	140	4,960	69
New Mexico	85	16	1,700	46	1,547	58
Texas	550	140	6,500	1,030	8,220	48
California	540	89	10,000	460	11,089	36
MORE HUMID STATES						
Minnesota	50	72	2.2	190	314	17
Georgia	85	23	12	210	330	15
Indiana	140	79	5.1	390	614	9
Illinois	160	95	3.2	393	651	7

Source: D.K. Todd, Ground Water Hydrology, New York and London, Wiley, 1959.

There is very little information on the spatial distribution and depth of occurrence of groundwater resources in the developing countries. Moreover, although abundant information is available in many developed countries, data on global or regional groundwater resources are very limited. Better documentation should be actively pursued, particularly in those developing countries where groundwater needs are greatest.

Although irrigated land comprises only 13% of the world's total arable area, irrigation accounts for by far the largest proportion of the total water used by man (Table 3-7). Other non-agricultural water uses (for industry, mining and domestic purposes) are now increasing much faster than the use for irrigation. However, a considerable amount of this water is non-consumptive and is recycled, while irrigation continues to be a consumptive use. Irrigated agriculture will therefore continue to be the greatest water consumer in the future.

Within a region, country or river basin, the spectrum of uses and withdrawals of water will vary according to climatic and socio-economic conditions, and it is thus necessary to distinguish between consumptive and non-consumptive use. For example, Table 3-8 indicates that, among the countries covered, the highest annual withdrawals per caput occur in the United States and the U.S.S.R., where both irrigated agriculture and industry are highly developed. However, very high withdrawals also take place in non-industrialized countries such as Mexico and India, where there is a large use of water for irrigated agriculture. The figures for Czechoslovakia and the United Kingdom show that per caput demand may be quite low in industrial countries with very low demands for irrigation.

Table 3-7. Estimates of world water use, 1967, and projections to 2000

	Total use			Proportion of total use	
	1967	2000	Projected rate of growth 1967 - 2000	1967	2000
	....million m^3 ...		...% per year ...	.......%.......	
Agriculture					
Irrigation	1,400,000	2,800,000	2.1	70	51
Livestock	58,800	102,200	1.7	3	2
Rural domestic	19,800	38,300	2.0	1	1
Other					
Urban domestic	73,000	278,900	4.1	4	5
Industry and mining	437,700	2,231,000	5.0	22	41
TOTAL	1,989,300	5,450,400	3.1	100	100

Source: M. Holy, op. cit.

Water quality

The need for water resources, however, goes beyond quantity and must also consider quality. The harmful effects of waste disposal on quality are well known, but a major unseen problem is the increasing salinity of water resources with use. This is an inevitable process in nature, but man has greatly accelerated it and, with continued increases in the intensity of use, the problem will become greater.

Guidelines have been drawn up for interpreting the quality of water for irrigation[14]. Table 3-9 illustrates the application of some of these guidelines to the quality of water in three irrigated areas. The Mona project in Pakistan and the Pecos River in the United States would be classified as having severe or increasing water quality problems for irrigation. The Tigris River would be classified as having no problem, although sodium concentrations would be regarded as borderline.

Increased salinity in water supplies results from the two basic processes of salt loading and salt concentrating. Salt loading is due both to natural causes such as surface run-off and to man-made sources such as industrial waste and return flows from irrigated land. The relative effects of salt loading and salt concentrating on salinity concentrations for the Colorado River in the United States are shown in Table 3-10. While 59% of the average salinity concentration over the 20 year monitoring period was attributable to natural causes (including evaporation), 41% was due to man's activities (mainly irrigation, which accounted for 37%).

14/ R.S. Ayers and D.W. Westcott, Water Quality for Agriculture, Irrigation and Drainage Paper No. 29, Rome, FAO, 1976.

Table 3-8. Water use in selected countries, 1965

Country	Total	Municipal and rural water supply	Agriculture	Industry
	m^3 per caput	.... % of total		....
United Kingdom	200	31	3	66
Czechoslovakia	285	13	6	81
India	600	3	96	1
Japan	710	10	72	18
Mexico	930	4	91	5
U.S.S.R.	1,000	8	53	39
United States	2,300	10	42	48

Source: United Nations, The Demand for Water, op. cit.

Another major concern in the developing countries is the provision of safe drinking water and the hygienic disposal of wastes. A recent WHO survey, covering 1,600 million people (including those of 88 developing countries), found that 77% of the populations surveyed were not satisfactorily served by community water supplies.[15]

Irrigation problems

Irrigation, or the controlled use of water for agriculture, is playing an increasingly important role in increasing production and in reducing its instability. In the Near East, for example, 70% of the total agricultural production is derived from the 35% of the cultivated area that is irrigated.[16] The benefits of irrigation go far beyond the mere provision of water, since it creates conditions suitable for the optimum use of other inputs, such as fertilizers and high-yielding varieties.

Table 3-9. Water quality in three selected irrigation areas

	Salinity ECw[1]	Sodium SAR[2]
Guideline		
No problem	Below 0.75	Below 3
Increasing problem	0.75 – 3.0	3–9
Severe problem	Above 3.0	Above 9
Irrigation area		
Mona project, Pakistan, 1968	3.60	38.0
Pecos River, United States, 1946	3.21	8.6
Tigris River, Iraq, 1966–69	0.51	2.5

Source: R.S. Ayers and D.W. Westcott, Water Quality for Agriculture, op.cit.

[1] Electrical conductivity, expressed in mmhos/cm. -

[2] Sodium absorption rate, adjusted for calcium and magnesium content.

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[15] United Nations, The Demand for Water, op. cit.

[16] M. El Gabaly, Seminar of Committee on Water Research, Cairo, 1976.

Table 3-10. Effect of various factors on salt concentration of Colorado River, United States, 1942-61 1/

Factor	Cumulative concentration	Share of total
	mg/1	%
Natural sources	334	47
Evaporation	80	12
Irrigation (salt contribution)	178	26
Irrigation (consumptive use)	75	11
Municipal and industrial sources	10	1
Exports out of the basin	20	3

Source: United States Environmental Protection Agency, Summary Report, 1971.

1/ At Hoover Dam.

The total irrigated area of the world was 223 million hectares in 1975, and is expected to rise to 273 million hectares by 1990. Table 3-11 shows estimates of the area equipped for irrigation in the developing market economies in 1975, and targets for new irrigation and the improvement of the existing irrigation in these countries by 1990. Irrigation accounted for 66% of the cropped area in Asia in 1975, 19% in the Near East, 13% in Latin America, and only 3% in Africa. The demand for water for irrigation in the developing market economies would increase between 1975 and 1990 by 438 km^3, or more than 30% of the total world use of water for irrigation as estimated in Table 3-7 above.

The major irrigation problems arise from water losses due to ineffective or badly managed systems, and from salinity and waterlogging associated with inadequate drainage. As regards the former, the targets shown in Table 3-11 indicate the need for the improvement of almost half of the existing main and on-farm irrigation systems in the developing market economies. About 40% of these improvements are classified as "major". Even under optimum conditions of efficiency, some 25 to 30% of the water used in irrigation schemes is not utilized by the crop, but is lost in run-off, evaporation and percolation. More often the figure is 50% or even more. More efficient irrigation systems, however, require large investments, which must be returned in higher yields and income. The cost of the improvements included in Table 3-11 has been estimated as U.S.$23,000 million at 1975 prices.

As regards salinity and waterlogging problems, salinization is very often associated with irrigation. The causes include unsuitable soils, irrigation with poor quality water (as discussed above), inadequate soil drainage to remove soluble salts, a high water table, and a high evapotranspiration rate. It is estimated that about half of all the irrigated lands of the world have been damaged by salinization, alkanization and waterlogging.17/

Past neglect of drainage, in conjunction with irrigation, has reduced the productivity of millions of hectares, which must now be reclaimed if at all possible. In some cases, large areas of irrigated land have had to be abandoned as a result of soil salinization. The serious extent of this problem is illustrated in Table 3-11. Improved drainage should be extended to 52 million hectares of irrigated land in the developing market economies, much of it within the 45 million hectares requiring improvements in the irrigation system. The cost of the drainage improvements shown in Table 3-11 has been estimated as U.S.$13,700 million at 1975 prices.

17/ FAO/UNESCO, Soil Map of the World, op cit.

Table 3-11. Irrigation and drainage in the developing market economies, 1975, and targets, 1990

	Africa	Latin America	Near East	Asia	Total
	.... thousand ha.				
IRRIGATION					
Equipped irrigation area, 1975	2,610	11,749	17,105	60,522	91,986
Targets, 1990					
New irrigation	960	3,101	4,295	13,848	22,204
Improvements to existing irrigation	783	4,698	9,789	29,718	44,988
of which minor	522	2,349	6,368	17,614	26,853
major	261	2,349	3,421	12,104	18,135
	.... km^3				
Increased water demand	20	33	44	341	438
DRAINAGE	.... thousand ha				
Equipped drainage area, 1975	7,044	46,585	18,212	62,501	134,342
Improvement targets, 1990	5,900	19,245	9,643	43,396	78,184
of which on irrigated land	1,177	2,018	7,076	42,152	52,423
on non-irrigated land	4,723	17,227	2,567	1,244	25,761

Source: United Nations Water Conference, Water for Agriculture, 1977, Annex I.

In Pakistan, out of a total of 15 million hectares of irrigated land, about 11 million suffer from salinity, waterlogging or both, resulting in pronounced reductions in crop yields. In Iraq, more than 50% of the Lower Rafadain Plain suffers from salinity and waterlogging. In Syria, about 50% of the irrigated land in the Euphrates Valley is seriously affected, with crop losses worth about U.S.$ 30 million annually. In Egypt, some 0.8 million hectares, or 30% of the total, are affected, and in Iran over 15% of the irrigated lands.18/

Among other factors to be considered, the most important is disease transmission as a result of irrigation. Schistosomiasis is the most serious of the diseases concerned. Irrigation schemes provide a natural environment for its spread, and in one case 60% of the adults and 80% of the children are affected.19/ Malaria can also thrive on irrigation projects, when havens for vector breeding become established as a result of defective planning and water management.

The problems of irrigation are immense, but the crop production potential due to irrigation is equally great. The solution lies mainly in the rehabilitation and improvement of existing irrigation schemes and the proper installation and subsequent management of new ones. The installation of new schemes will be particularly important in Africa, where irrigated areas are now expanding rapidly.

18/ M. El Gabaly, op. cit.

19/ M.A. Amin, Problems and Effects of Schistosomiasis in Irrigation Schemes in the Sudan, Khartoum Bilharzia Project

GRAZING LAND AND FORAGE RESOURCES

Grazing land and forage provide the major part of the nutrition of the world's ruminant and equine livestock population, which totalled a little less than 3,000 million head in 1976 (Table 3-12). In many countries they provide no less than 80% of the total feed consumed, and on a world basis they are by far the most important resource on which to base the future expansion of milk and meat production.

Grazing and forage production is the most extended form of land use on a world scale. The statistical information indicates about 30 million km^2 of permanent pasture (Table 3-13), which is some 23% of the world's land area. About half of the total is located in the developing market economies. Permanent pasture is defined as land used for five years or more for herbaceous forage crops, either cultivated or growing wild. But, depending on the reporting of various countries, large stretches of land with scattered tree and shrub growth or more prominent wood components are classified under forests and woodland, in spite of their sometimes substantial grazing use. Similarly, large areas statistically classified as "other land" are used for rough grazing or nomadic grazing in the arid zones and the tundras. If these resources and also the areas used for shorter-term forage production are taken into account, it can be assumed that almost half of the land area of the world is used for grazing and forage.

The vast majority of grazing land and forage resources is determined by natural vegetation which has developed to favour forage use through the interaction of climate and soils, and also to a considerable extent through the effect of grazing animals, wild as well as domesticated, and man's activities such as forest and bush clearing, burning, mowing and cropping. In large areas these influences date back to prehistoric times. In others there are historical records showing how pastures have developed as secondary vegetation as a result of forest clearing, or other major man-made vegetational changes, including the planting of improved pastures. From a strictly scientific point of view, there are presumably not many vegetation types used as grazing land today which could be classified as unchanged climax vegetation. This is even true for the large areas of primary vegetation supporting grazing use, such as grasslands, prairies, steppes and savannas.

A basic understanding of the major factors determining the present vegetational composition, growth characteristics and forage value of grazing and forage resources is very often a prerequisite for estimating the present and potential productivity of these resources, and developing viable concepts for their rational use, management and improvement. In spite of considerable work done in some areas, the widespread insufficiency or even complete lack of reliable basic data is a major obstacle to the more accurate determination of the productivity and quality of these resources for animal production, and of the stages of deterioration which call for specific programmes for reclamation and improvement.

Table 3-12. Numbers of ruminant and equine livestock, 1976

	World total	Developing market economies	
	.... million head		% of world total
Sheep and goats	1,451	754	52
Cattle	1,214	696	57
Buffaloes	132	98	74
Horses, mules and asses	123	74	60
Camels	14	12	86

Source: FAO Production Yearbook 1976, Rome, 1977, p. 193-201.

Table 3-13. Extent and distribution of permanent pastures, 1975

	Permanent pastures
	million km^2
Developing market economies 1/	14.4
Africa	6.9
Far East	0.3
Latin America	5.3
Near East	1.9
Asian centrally planned economies	3.6
TOTAL DEVELOPING COUNTRIES	18.0
Developed market economies 1/	8.6
North America	2.4
Western Europe	0.7
Oceania	4.7
Eastern Europe and the U.S.S.R.	3.9
TOTAL DEVELOPED COUNTRIES	12.5
WORLD	30.5

Source: FAO Production Yearbook 1976, op. cit., p. 45-56.

1/ Including countries in other regions not specified.

With a few exceptions, grazing lands prevail in those areas which have severe restrictions for crop cultivation. The most important of these restrictions on a global scale is insufficient rainfall, but soil characteristics such as low fertility, steep slopes, shallowness, waterlogging or flooding, or other reasons such as low temperatures, short grazing seasons and inaccessibility through lack of adequate infrastructures, may likewise be important. Depending on the climate and on the growth characteristics of the forage vegetation, most forage resources provide feed for animals of sufficient quantity and quality only in part of the year. This results in a seasonal pattern of production, if no compensatory feed resources are available or are established through such practices as the alternate use of different vegetation types (including cultivated forages), forage conservation as standing hay, hay or silage conservation, or the use of byproducts. The annual productivity of grazing lands and forage resources varies from 1 ha supporting 3 or even 5 animal units on well-managed and fertile pastures in central Europe or Japan, to 50 to 60 ha being required to maintain 1 animal unit on arid grazing lands in Saudi Arabia or New Mexico (United States).

The vastness of the world's grazing land resources may be misleading in relation to their potential for animal production. Low productivity per unit of land is widespread in all areas of limited rainfall, or where other factors such as low fertility limit plant production. Misuse and neglect are more common than sound traditional pastoral systems or effective ranging systems that keep forage production and its use by livestock in a proper balance and introduce measures to maintain or improve productivity.

Degradation of grazing land and forage resources

The future of grazing land and forage resources is closely related to the development of sound land use concepts, based on improved ecological and agronomic data. The growth of the human population will further increase the pressure on these resources, either for conversion to cropland or for feeding increasing numbers of livestock.

Between 1955 and 1976 cattle numbers rose by 38% in the world as a whole, and 35% in the developing market economies (Table 3-14). They almost doubled in Oceania, and rose by 77% in eastern Europe and the U.S.S.R., 62% in the Near East, and 51% in Latin America. For sheep and goats the increase was only 21% at the world level but 28% in the developing market economies. The most rapid increases were in the Asian centrally planned economies (52%) and Africa (44%).

These increases reflect the rapidly expanding demand for livestock products, and are also partly due to improvements in animal health. In some areas they have put a heavy pressure on grazing and forage resources. This has led to the serious deterioration of grazing land, particularly in the Sahelian and Sudanian zones of Africa, and in parts of the Near East, the Mediterranean and North Africa. The grazing resources in these areas are to a large extent under arid and semi-arid conditions, and some of them have already been threatened for hundreds and sometimes thousands of years by overuse, leading to complete changes in the vegetation, which have left only shrubs of low palatability. Further increases in grazing pressure and aggravated misuse result in the complete devastation of all vegetation, which finally ends in desertification. The problem has been magnified by the encroachment of cropping on to the grazing area, as a result of faster population growth outside the range area. Similar problems exist in other arid and semi-arid areas, for example in continental Eurasia, in India and Pakistan, and in Northeast Brazil.

Table 3-14. Numbers of cattle, and of sheep and goats, 1955 and 1976

	Cattle		Sheep and goats	
	1955	1976	1955	1976
	.... million head			
Developing market economies 1/	514.3	696.3	587.8	754.3
Africa	95.0	129.9	150.3	216.8
Far East	214.8	254.0	130.5	176.6
Latin America	175.7	265.6	155.9	161.4
Near East	28.6	46.2	150.8	199.3
Asian centrally planned economies	57.5	71.6	101.6	154.8
TOTAL DEVELOPING COUNTRIES	571.8	767.9	689.4	909.1
Developing market economies 1/	225.0	302.0	364.8	359.6
North America	106.4	141.7	35.3	15.0
Western Europe	82.0	100.6	115.7	103.0
Oceania	21.7	43.2	170.1	205.0
Eastern Europe and the U.S.S.R.	81.2	143.9	146.7	182.0
TOTAL DEVELOPED COUNTRIES	306.2	445.9	511.5	541.6
WORLD	878.1	1,213.9	1,200.8	1,450.6

Source: FAO data and FAO Production Yearbook 1976, op. cit., p. 196-201.

1/ Including countries in other regions not specified.

Such grazing land can be reclaimed by reseeding with suitable forage species, including legumes and shrubs, and by the introduction of improved systems of grazing management. Such measures are costly, however, and it is also difficult to introduce the necessary changes in the prevailing socio-economic systems of nomadism and pastoralism, in pastoral legislation, and in administrative control. A major feature of these changes is the integration of the animal production of rangelands with improved forage production in neighbouring cropping systems, including those under irrigation. These or other forms of stratification may be the most promising ways to develop viable livestock industries in semi-arid areas, and to improve and maintain their always fragile but important grazing resources. FAO and UNEP are cooperating in a programme on Ecological Management of Semi-Arid Rangelands, to support government efforts of this kind.

Deterioration is less of a problem in the humid and sub-humid areas of the tropics and sub-tropics, where various types of savanna and woodland provide the major grazing and forage resource. These areas sustain about 40% of the world's livestock population (Table 3-15). Major deficiencies in such areas are the rapid decline in the feeding value of forage grasses during rapid growth in the rainy season, and the length of the dry season, during which good quality forage is scarce. In some areas, particularly in Africa, major animal diseases such as trypanosomiasis have so far prevented heavy grazing pressure. In others, as in parts of Latin America, major nutrient deficiencies of soils and plants are severe limiting factors for livestock production. Locally, however, overgrazing may be a serious problem, and considerably reduce the productivity of the sward. The incorporation of tropical legumes in existing swards or their complementary planting in improved areas, the control of the regrowth of undesirable and noxious species, and improved systems of animal husbandry, including grazing management, are among the most promising measures to develop the productivity of these grazing resources and to counteract deterioration. As in the arid and semi-arid areas, however, solutions must be found to the socio-economic constraints.

In certain areas, for example in West Africa, the improvement of humid and sub-humid grasslands can reduce grazing pressure in the arid and semi-arid parts of the same country. Thus there is a complementary effect, which benefits both types of grazing resource.

Table 3-15. Permanent pasture, forest and woodland and livestock numbers in the humid and semi-humid tropics, 1972-75

	Permanent pasture	Forest and woodland		Livestock numbers		
			Cattle	Sheep	Goats	Buffaloes
	.... million ha	......	....	million head	.....	....
Africa	345	521	86	34	53	–
Central America	57	51	35	3	6	–
South America	198	814	134	44	21	–
Asia	29	341	194	30	62	75
Oceania	26	160	6	–	–	–
Total of above	655	1,887	456	111	142	75
WORLD	2,992	4,035	1,132	1,057	887	126

Source: W.J.A. Payne, Problems and advances under humid tropic conditions, Proceedings, Second World Conference on Animal Production, Urbana, American Dairy Science Association, 1968, p. 52-60.

Grazing and forage resources in the area of the tropical rain forests vary in size and importance. Those being developed as a sub-climax on alluvial river banks which are periodically flooded, as in the Varzea of the Amazon Basin, may be very productive (1 animal unit/ha). Those that are being increasingly developed in forest clearings in the lowlands and in lower mountain elevations compete with forestry and with other agricultural uses. Plantings with suitable forage grasses and legumes can develop productive swards, but soil deterioration because of less protection against insolation and increased leaching of nutrients must be carefully monitored in order to avoid irreversible effects. Increased research is necessary to develop land use systems in which grazing and forage resources might find their proper place in the derived ecosystem.

The development of grazing resources in various forest types at higher elevations in tropical and sub-tropical mountain areas is very extensive, for example in the Himalayas and the Andes. The process, which is still going on, has led to a considerable reduction in forest cover during the last few centuries. The grassland cover developed as secondary vegetation by the spread of indigenous or introduced species is often poor, not only from a production point of view, but also as a soil cover. Soil erosion is very common, and is aggravated by indiscriminate and uncontrolled grazing and overstocking. Lack of attention to common grazing land in small farm areas, lack of knowledge of methods of improvement, socio-economic constraints, and increasing pressure on the use of agricultural land place this important resource in danger of further deterioration. Increased productivity of suitable cropland, including forage cultivation using new production systems with the necessary inputs, is one major tool to reduce grazing pressure on these mountain lands. It must be followed by better adapted grazing systems, which may include the partial improvement of existing swards by reseeding, fertilization and irrigation. The stratification of animal production between highlands and lowlands might be another important improvement. Reduction in grazing pressure would at the same time allow reforestation to improve vegetation cover and erosion control.

High mountain grassland above the tree line, often referred to as alpine grassland, has been under considerable grazing pressure, primarily by sheep and goats and by wildlife, in many parts of the world. The short grazing season and low productivity of these areas have allowed their use only in systems of transhumance, a form of stratification with other grazing resources of lower elevation. Problems of deterioration do not seem to be serious, but there is a widespread lack of information. The improvement of more productive forage resources at lower elevations is the major means to reduce grazing pressure in these areas, as has been demonstrated in the European Alps.

This review of grazing and forage resources is incomplete, and does not cover all important areas of the world. But the grasslands of the humid and cool temperate climate should be mentioned, because of the high productivity they have reached in some areas of western and central Europe and in New Zealand. Developed as a secondary vegetation replacing deciduous forests, they have found their place between the croplands (including forage crops) and the forested land, and have varied in extent over the centuries. Although their productivity differs with soil, water and atmospheric conditions, the deterioration of these grasslands was very common in Europe in the past, as a result of uncontrolled selective grazing and exploitation of soil nutrients, sometimes since neolithic times. The heath areas of Scotland and Germany remain visible signs of this degradation. Modern grassland science has developed the basis for improvements to develop, introduce and maintain productive forage grasses, legumes and herbs in the sward, using fertilization and well-adapted management systems, often combining grazing and mowing to secure part of the forage for conservation for the winter feeding period. With the increase in forage production on the land best suited to it, and with the necessary socio-economic changes, the less productive grassland is increasingly reforested or used for recreational purposes.

Grazing and forage resources cannot be considered in isolation from other types of land use. For various areas there is considerable knowledge of how deteriorated grazing lands can be reclaimed, and how improvements in productivity for animal production could be introduced in existing grazing land ecosystems. But substantial further research is needed in many areas, particularly in the developing countries, to establish the necessary data base and to develop methods and management systems applicable to existing socio-economic conditions. This should include research on ecologically and economically sound decisions on where existing grazing land should be converted into cropland or forest, and where cropland of low productivity might be more suitable for grazing land.

FOREST RESOURCES

A forest is a community or an ecosystem of biotic and non-biotic components, consisting predominantly of trees or other woody vegetation growing more or less closely together. In addition to the trees, biotic components are shrubs, grass and other plants, and big and small animals. The non-biotic components are soil and the local climate prevailing within and in the vicinity of the forest. Each individual component has an influence on the others, resulting in a sometimes fragile ecological balance.

These communities or ecosystems can be very complex, as in the case of the tropical evergreen rain forests, or much more simple, as in the coniferous boreal forests. As a consequence of various factors of degradation or transformation, such as fire, shifting cultivation, grazing or commercial cutting, the complex primary forests, both tropical and temperate, are succeeded by more simple, but sometimes more economically useful types of secondary forest. Some of these transformations may be the outcome of deliberate management plans.

A forest is therefore more than the juxtaposition of individual trees. It creates its own environment: the forest environment. The classical concept of forests, based in particular on the closeness of the trees, has sometimes been expanded to include any land carrying scattered trees or even woody vegetation. Since there is no widely accepted clear definition of what should be classified as forest, and since no comprehensive global survey has ever been made, it is impossible to give a reliable estimate of the world area under forests.

It is helpful to distinguish between the closed forests, where tree crowns cover more than 20% of the ground, and which (more or less) enjoy a forest environment, and the open forests, which represent all the remainder of the area carrying a woody vegetation, but which lack the true forest environment. The closed forests have the statistical advantage of being easy to identify either from the ground or by remote sensing, so that their area is relatively easy to evaluate.

It has been estimated that about 4,300 million hectares, or about a third of the world's land area, may be covered by some woody vegetation,20/ but this figure has to be taken as a mere indication. The area of closed forest can be more accurately estimated at 2,970 million hectares (Table 3-16), or about a quarter of the land area. A little more than half of the closed forest is in the developed countries. The forest areas of the world are also shown in Figure 3-1, where they are divided into coniferous and broadleaved.

The roles of forests

Forests provide both goods and services. The goods are not only the woody products obtained from the trunks of the trees, but also products derived from the other parts of the trees and from other components of the forest community. The woody products are numerous and extremely varied: timber and sawnwood for furniture, dwelling construction and public works; wood panels of all kinds for furniture, walls, doors and shuttering; pulpwood for pulp and paper (newsprint, cultural and wrapping papers) and carton and dissolving pulp for rayon; poles, posts, mining timbers, railway sleepers and fuelwood. The non-woody products are even more varied, ranging from fruits, fodder and game meat to pharmaceutical products and honey.

20/ R.G. Fontaine, 'Forestry and environment, Geoforum, 10, 1972.

Table 3-16. Area of closed forest, 1975

	Developed countries	Developing countries	Total
	.... million ha	....	
North America			665
Canada	325		
United States	305		
Mexico		35	
Europe	135		135
U.S.S.R.	770		770
Africa			190
North Africa		1	
West Africa		20	
Central Africa		150	
East Africa and islands		19	
Southern Africa	-	-	
Central and south America			665
Central America and Caribbean 1/		70	
Andean region		220	
Brazil		345	
Southeast Latin America		30	
Asia and Far East			545
West Asia		10	
South Asia		70	
Continental southeast Asia		100	
Insular southeast Asia		125	
East Asia		125	
Oceania	50	40	
Japan	25		
WORLD	1,610	1,360	2,970

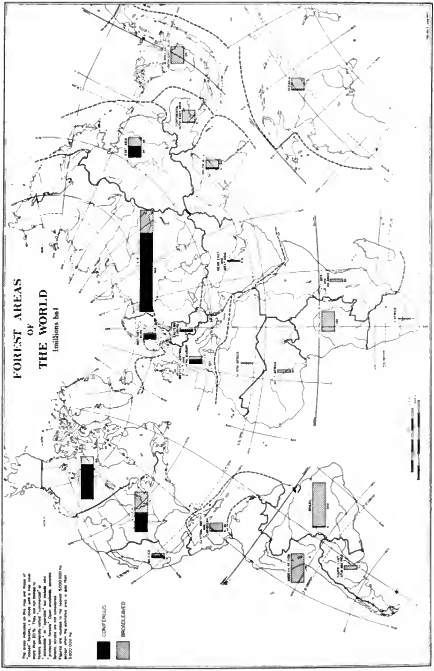
Source: Canadian Forest Service, Canada's Forests, 1976; FAO, Forest Resources in the European Region, Rome, 1976, p.3; R. Persoon, Forest Resources of Africa, Stockholm, 1975; FAO/IBDF, Una Análise Estatística da Actual Situação Florestal Brasileira, Brasilia, 1976; FAO, Forest Resources in the Asia and Far East Region, Rome, 1976, p. 3.

1/ Excluding Mexico and including Guyanas.

As a transition from goods to services, there is the role of the forest as a traditional means to rebuild soil fertility. This is reviewed in a later part of the chapter which discusses shifting cultivation.

The services rendered by forests (and particularly by the closed forests) are as numerous and sometimes as essential for mankind as the goods they produce. Forests play an important role in protecting soils against erosion or degradation, in producing a continuous flow of clean water, in reducing the danger of flooding, and in protecting crops and settlements against dessicating winds or excessive temperatures. It is no coincidence that desertification and deforestation are parallel phenomena. The role of forests in the

Figure 3-1. - Forest areas of the world



regularization of the local micro-climate is now widely accepted. On the other hand, little is known about the possible consequences of the massive destruction of forests for the climate of a whole country, region or continent.

Forests, and more generally trees or green vegetation also provide beauty, amenity and recreation, and in some industrial and urban civilizations they are as much a factor of man's psychological balance as of ecological balance. The use man makes of the forest is characteristic of the type of society he lives in (Table 3-17). Traditional aboriginal communities are heavily dependent on the forest for their living and even for their survival. The forest provides them with food, fodder, game meat, medicines, honey, and fuelwood. The disappearance of the forest or even the disturbance of the forest environment may cause the destruction of these societies. At the other extreme, urban and highly sophisticated civilizations tend to consider the forest more as a source of beauty or recreation, and possibly also of clean water, than as a supplier of goods, without realizing that these goods are necessary for the survival of their very type of civilization. For example, the average United States citizen consumes for paper alone the equivalent of 1 m^3 of roundwood per year, which is approximately the annual sustained yield of a third of a hectare of average temperate forest. On the other hand, in most developing countries the corresponding figure is about 0.05 m^3. The relative consumption of fuelwood, however, is reversed as between the two groups of countries.

Table 3-17. Use of the forest according to type of society

	Developed	Developing
Goods	More industrial wood (in particular pulpwood) than fuelwood. Little use of minor products such as fodder or game meat.	Wood products used in primary form (poles, posts, and mostly fuelwood). Importance of minor non-woody products.
Services	Soil and particularly water protection. Amenity and recreation roles are prominent and increasing.	Soil and water protection, but the essential role is the regeneration of fertility in shifting cultivation.

Almost all the services provided by forests are related to their role in the ecological balance, and are thus concerned with the environment. However, the two roles of the forest in providing goods and services are closely interdependent. If man destroys or overexploits a forest for the production of goods, he may also destroy its capacity to provide services, and thus its environmental value. In the remainder of this discussion both roles of the forest will therefore be reviewed jointly.

Evolution of the world's forests[21]

In the developed countries, with few exceptions, forest cover is generally stable or even increasing slightly. In France, for instance, the area covered by forest has increased by probably more than a third since the start of the century. A balance between agricultural and non-agricultural land has already been achieved, to the extent that in many cases a natural forest of poor commercial value has invaded the abandoned marginal agricultural lands.

The situation is completely different in the developing countries, where no balance has yet been obtained between agricultural and non-agricultural land. Moreover, the very widespread (and up to now unavoidable) method of shifting cultivation does not permit a distinction between forest and non-forest land, because a plot now under forest cover is an agricultural plot in perspective.

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[21] The following refers only to closed forests, unless open forests are explicitly mentioned.

The closed and open forests of the developing world are mostly located within the inter-tropical belt. Within this belt, forests are not homogeneous. Their structure, physiognomy and composition vary, mainly but not exclusively (e.g. mangrove forests and mountain forests) according to the temperature and rainfall and their distribution over the year. Tropical forests are usually classified according to their climax type, whether the climax vegetation still exists or has already been destroyed. Three belts, approximately parallel to the equator, are generally identified in Africa, Asia and Latin America.

On both sides of the equator there is the tropical moist evergreen forest belt, which is also called the rain or humid or moist tropical forest belt. Tropical moist deciduous forest belts are located north and south of this belt. They are transition belts between the almost permanently humid and green forest and the dry one. Dry tropical forest belts are located north and south of them, ending to the north in the Mexican, the Sahara and the Asian deserts, and to the south in the Chilean, South African and Australian deserts, where forests cease to exist. All these types of forest have been extensively cleared and sometimes completely destroyed in the past, and the clearing and destruction continue.

In the humid tropical belt, as well as part of the transition belts (moist deciduous forest), the main factor causing destruction is clearing for agriculture, mostly by shifting cultivation. As discussed later in this chapter, shifting cultivation is not an absolute evil, but becomes dangerous for the maintenance of the forest environment and consequently for the environment as a whole if the duration of the forest fallow is too short, i.e. if the population is too dense. Most of the modern export or market-oriented logging operations are located in the humid tropical belt, but they do not seriously affect the environmental value of the forest, since they generally take out of it at most a quarter of the standing volume. However, they open up formerly inaccessible areas to land-hungry farmers and shifting cultivators.

Alarming estimates have been made about the destruction of the humid tropical forest. The present world area of closed humid tropical forest has been estimated as 935 million ha (506 million in Latin America, 254 million in Asia, and 175 million in Africa).[22] Some authors estimate a rate of destruction as high as 1.5% or even 2% per year, which would mean the disappearance of all tropical humid forest in less than 50 years. No global assessment can be made of these figures, but accurate estimates have been made in some specific cases of the clearing of tropical forest for agricultural purposes.

In the Azuero peninsula in Panama, it was found that, out of a total mountainous forest area of 215,000 ha, 92,000 ha, or 42%, had been cleared for agriculture between 1954 and 1972.[23] Northern Thailand presents a classic example of clearing followed by increased floods in the watershed area of the Mae Nam River. At the beginning of the century over 39,500 km^2 of the area were covered with forests, but an inventory carried out in 1956 showed that 58% had been felled and were either devoted to shifting cultivation or existed in the form of old clearings of secondary growth.[24] In the Ivory Coast, aerial photographs taken in 1956 and 1966 showed how shifting cultivation had reduced the forest cover by 30% during this period; this rate of clearing has continued, so that now only 5 million ha are left out of the 15 million ha of forest believed to exist at the beginning of the century.[25] In the Philippines, about 350,000 ha are being cleared annually by shifting cultivation, and one million ha were cleared in Mindanao alone between 1960 and 1971.[26]

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[22] A. Sommer, Attempt at an assessment of the world's tropical forests, Unasylva, 112-113, p. 3-24.

[23] UNDP/FAO, Reconocimiento de los bosques y inventario detallado de Azuero, Inventariación y Demostraciones Forestales - Panama, 1972, Vol. 3, p. 169.

[24] FAO, Report to the Government of Thailand on Forest Industry of the Northern Teak Bearing Province, FAO Report No. 895, Rome, 1958.

The above examples show that apparently pessimistic estimates of the disappearance of the humid tropical forests cannot be taken lightly. However, it must be emphasized that the clearing of the original humid tropical forests does not always and automatically mean the destruction of the forest area or represent a danger for the environment. It may be more usefully or adequately replaced by, for instance, a good pasture, a good artificial forest, industrial or fruit tree plantations, or by shifting cultivation with an adequate period of fallow. There are numerous examples of the beneficial effects of forest clearing, even in the forestry field proper, such as the regeneration of Dipterocarps in eastern Asia, Aucomea in Gabon, and Cedrela and Swietenia in Latin America.

It is obviously difficult to draw a clear line of demarcation between the three main forest belts in the developing countries. The wetter parts of the transition forest belts (the moist deciduous tropical forest) possess to varying degrees the features already described for the moist evergreen forest. Their drier parts have many similarities with the dry forest belts, which will now be briefly discussed.

Except in their more arid parts, the dry belts are more densely populated than the humid belt. Many moist forests remain under forest precisely because of the low density of the population. Consequently, the area of closed forest is proportionately much smaller in the dry belts than in the moist, evergreen belt. The dry belts are largely made up of savannas, carrying shrubs and scattered trees. Shifting cultivation affects the dry belts too. Although its effects are less spectacular than the drastic changes in landscape that occur with the clearing of the impressive high evergreen forest, it may be much more dangerous since the ecosystem is more fragile.

The dry belts are generally little affected by commercial, market-oriented and industrial logging operations, but their trees are of paramount importance for domestic uses such as poles, posts and, above all, fuelwood. The use of fuelwood in the dry or transition tropical belts is economically so important and has such serious implications for the environment that it is discussed separately below.

Uncontrolled grazing, browsing by animals, and the cutting of branches by herdsmen are other important factors causing the degradation and often the destruction of dry and transitional forests, whether closed or open. In addition, during the dry season fires plague immense areas of the open forests throughout the world. In the developing countries they are generally started by herdsmen trying to renew the grass, or in the shifting cultivation plots. Some of the related problems are reviewed later in discussing shifting cultivation and also desertification.

25/ J.P. Lanly, Regression de la forêt dense en Côte d'Ivoire, Bois et Forêts des Tropiques, 127, p. 45-59.

26/ FAO, Environmental Aspects of Natural Resources Management: Forestry, Rome, 1971.

Fuelwood[27]

Of all the wood consumed annually in the developing countries, 82% (1,000 million m^3) is used for fuel. The contribution of wood fuel to total energy use is as high as 58% in Africa (Table 3-18). Fuelwood consumption is mainly for domestic use, with charcoal accounting for part of the total.

Table 3-18. Estimates of contribution of wood fuel to total energy use in developing regions

Region	Contribution to total energy use
	%
Africa	58
Far East	42
Latin America	20
Near East	14

Source: FAO, The State of Food and Agriculture 1976, op. cit., p. 90.

This massive dependence on fuelwood, together with the localized character of wood supply, puts increasingly heavy pressure on the tree cover and other woody vegetation, and can lead not only to destruction of the forest but to the complete removal of all tree and scrub cover. In the densely populated Gangetic plain, for example, the forest cover has been reduced to 0.35% of the land area in West Bengal and about 2% in Uttar Pradesh.[28]

The impact of the demand for wood fuel is felt most heavily around centres where population and processing industries are concentrated. The annual use of 3 million m^3 of wood for fuel in Bangkok is felt over a large part of Thailand.[29] Even in the sparsely populated region of the Sahel, areas surrounding small and medium-sized centres of population are largely deforested. Around one fishing centre in this region, where the drying of 40,000 tons of fish annually requires 130,000 tons of wood, deforestation extends as far away as 100 km. What is worse, the area affected is growing at a frightening speed. In one large town in the Sahel, where until recently nobody hauled fuelwood more than 50 km, it is now common to have to go as far as 100 km to get it.[30]

Where fuelwood becomes scarce or costly, it is substituted by animal dung and crop residues. The shortage of fuelwood weighs disproportionately heavily on the poorest. At prevailing prices it would, for example, absorb 15% of household income in the highlands of the Republic of Korea and up to 25% in the poorer parts of the Andean Sierra and the Sahelian zone, if it were available for purchase on the spot. The option of substituting commercial fuels as organic fuels disappear is beyond the means of the poorest people, and investment in stoves is also too costly for them. Thus for millions of people the progressive disappearance of fuelwood means the progressive disappearance of the means to cook and keep warm.

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[27] For a fuller discussion, see: FAO, The State of Food and Agriculture 1976, op. cit., p. 88-92.

[28] R.S. Mathur, Certain trends in the consumption of wood in India, Indian Forester, Jan. 1975.

[29] M.F.E. de Backer and K. Openshaw, Present and Future Forest Policy Goals, a Timber Trends Study 1970-2000: A Report Prepared for the Government of Thailand, FAO TA Report No. 3156, 1972.

[30] J.C. Delwaulle and Y. Roeberer, Le bois de feu à Niamey, Bois et Forêts des Tropiques, 152, Nov.-Dec. 1973.

It must therefore be expected that for the foreseeable future locally available wood and other organic materials will have to continue to meet most of the energy requirements in developing countries. The negative effects on forest resources and on the environment will unfortunately continue, and in many areas will become worse unless suitable action is taken in the immediate future. Many countries carry out programmes to provide fuelwood at the village level. In China and the Republic of Korea, trees have been planted for this purpose through community efforts in village woodlots, around farms and as larger plantations.

Wood resources in relation to demand

Wood cutting for market purposes is often accused of being the main cause of forest degradation or destruction, with concomitant effects on the environment. The above review already suggests that this opinion may have to be modified.

The productive capacity of a forest may be calculated on a sustained basis not only for the goods but also for the services it normally provides. The quantification of services is, however, often difficult.

A very dry forest may produce less than 1 m^3 of roundwood per ha per year, whereas the best artificial plantations may, in good conditions, produce more than 25 m^3 per ha per year. Each type of forest produces different types of wood suitable for different uses: dry open forest in the Sahel cannot produce better than fuelwood and poles, while a well managed temperate oak forest may produce very valuable veneer logs 200 years after its establishment.

When referring to the productive capacity of a forest or of forest land, one must not only speak in quantitative terms but also qualitatively. This is particularly relevant to tropical forests, because they (in particular the moist ones) are heterogeneous, with up to 300 species in the same forest, and only a limited number of species are at present accepted by the trade.

All the available information suggests that sometimes at the national level, but certainly at regional or sub-regional levels, the developed world is, or could easily be self-sufficient for most of the wood it consumes, both quantitatively and qualitatively. Removals do not seem to exceed productive capacity, so that, with proper management, it should be possible to safeguard the environmental role of the forests of the developed countries. Each inhabitant of the developed world has on the average more than one hectare of forest at his disposal to provide the wood products he requires. As the population of the developed world is growing only slowly and the area covered by forest is increasing slightly, there should not be any crisis, at least in this century. The present productive capacity of average temperate closed forest is around 2 m^3 per ha per year on a sustained basis, which is much more than is likely to be needed. Moreover, in many developed countries forests are not managed intensively enough to produce to their maximum capacity.

It may therefore be concluded that during this century wood demand, and consequently wood cutting, should not normally create an environmental crisis in the developed world. Urbanization is a more serious cause of forest destruction than wood removals in these countries. A possible exception is Japan, which possesses only 25 million ha of forest land for a population of 112 million, but this highly industrialized country makes up its wood deficit by importing logs, which it pays for by exporting sophisticated industrial goods. However, Japan's domestic forests are quite adequately managed. Japan imports 50 million m^3 of logs a year, but the other developed countries import only marginal amounts of tropical woods (about 3% of their consumption). Except for very special qualities of wood, they could probably do without these imports, provided they apply more intensive management to their own forests.

The present consumption of the developing countries is about 1,300 million m^3 of roundwood, or 0.4 m^3 per caput per year, of which 82% is fuelwood. Assuming that, according to the United Nations medium variant, the population of the developing world reaches about 4,900 million in the year 2000, and that per caput GNP increases by 3.8% per year, the total consumption of wood products would reach the level of 2,400 million m^3 (0.5 m^3 per caput), over 75% of which might still be fuelwood. At the global level, such needs could be satisfied if the productivity of the closed forests of the developing countries could be raised to 2.0 m^3 per ha per year. This seems technically possible, at least in quantitative terms. Thus, if the developing world were a single market community, and if the wood products could be transported over long distances, there should not be any serious problem.

This optimistic view is reinforced by the fact that fuelwood, which is likely to represent 3/4 of the developing world's requirements in the year 2000, can be obtained not only from closed forests but also from the large area of open forests, from linear plantations, from shrubs and even from agricultural residues. The supply base of fuelwood is so wide that its consumption is a cause of the degradation and destruction of the forest and environment only in dry areas, or exceptionally in those more humid areas where the local population is extremely dense. Excluding fuelwood, the requirements of the developing world in the year 2000 would be in the region of 550 million m^3 of roundwood, and at the global level it does not seem impossible to obtain this quantity on a sustained basis from the 1,400 million ha of closed forest that now remain. This represents an annual cut of only 0.4 m^3 per ha, which is less than 0.2% of the average standing volume of 200 m^3 per ha. Moreover, Figure 3-1 suggests that at the regional, and possibly also at the subregional and sometimes at the national level, the developing countries at present have enough forest area to be self-sufficient in wood products, provided of course they form some regional or subregional economic or trade communities to allow the countries richly endowed with forests to supply the poorer ones.

Table 3-19. Area of closed forest per caput, developing countries, by continent, 1975

Region	Closed forest	Population	Closed forest per caput
	million ha	million	ha
Latin America	700	324	2.16
Africa	190	376	0.51
Asia	430	2,142	0.20
Oceania	40	4	10.00
Total	1,360	2,847	0.48

Source: Table 3-16 and United Nations population estimates.

Table 3-19 shows the present area of forest available for each inhabitant of the developing countries. It would seem that Asia already has few forests to supply its huge population but this is largely compensated by the predominance of Dyptocarpacean forests, most species of which are now accepted by markets. Moreover, China, which has about 40% of the continent's population, has embarked on a massive reforestation programme. The fact that the market now accepts just a few species from the moist tropical forest should not cause excessive preoccupation. Constant technological breakthroughs make an increasing number of species acceptable to the market, as the increased demand tends to be accompanied by an increased use of new species, so that the number of newly used tropical species is increasing all over the world.

On the other hand, it is true that a great part of the supply base, namely the area of closed tropical forest, is shrinking. As was noted earlier, according to some authors it is shrinking at an alarming rate within the moist tropical forest belt. It has also been seen that the main cause of the disappearance of the tropical forest is clearing for agriculture. Shifting cultivation does not always destroy the forest and may just replace it by secondary forest, which is also productive, and sometimes more productive than the original one. It is often forgotten that untouched, virgin forest does not produce any wood, as growth is balanced by natural mortality with no benefit to mankind. Moreover, original or virgin forest can be replaced by more productive land use, which (particularly in the framework of agri-silvicultural methods) may, if properly devised and managed, play an environmental role almost as satisfactory as that formerly played by the original forest. Nigeria, for example, is now replacing its natural rain forest (except in some reserves) to meet the needs of its large population. Since there are no accurate figures of the rate of clearing and destruction of the tropical forest, no estimate can be made of the area of intensively managed new forests necessary to make up for it. In general, however, in spite of some gaps, enough is known about tropical silviculture and forest management to make up for the shrinking of the area of the closed natural forest through an increase in the productive capacity of the land.

No longer taking a global but a more local view, there are two main circumstances in which specific measures may have to be taken locally to prevent or make up for the degradation or destruction of the forest, together with the degradation of its environmental role. First, some fragile or critical areas, for instance on steep slopes of erodible soils or important water catchments, should never be cleared. This applies also to certain natural forest reserves which might be needed for the conservation of some ecosystems, genes and species, including wild animals, and for the survival of aboriginal communities. Second, wood products (except paper and some sophisticated secondary products) are bulky, and cannot economically be shipped over long distances. This is particularly the case with fuelwood and wood for domestic use, which are employed in a round or unprocessed form. For this reason, even in countries like Cameroon or Nigeria, which range from the humid tropics with particularly good forest potential to the dry tropics, it may be necessary to create new forests close to the markets.

On the basis of the best available information, it may be concluded that the risk of degradation and destruction of the environmental role of forests will be serious only in areas of heavy population pressure and difficult conditions for tree growth. In such areas, action is urgently required in several fields if further harmful degradation is to be avoided.

First, the quantitative and qualitative monitoring of the evolution of tropical forest cover, already initiated on a pilot basis by UNEP and FAO, should be continued and extended. In addition, each country should periodically carry out a national forest inventory, geared not only to environmental but also commercial purposes. This is the only way to compare possible supply with demand, and estimate the pressure which may be exerted by cutting operations on the forest area, its composition and its role in the environment.

Second, critical or fragile areas, including natural reserves for ecosystem conservation purposes, may have to be preserved from clearing or commercial exploitation. In some cases it may be sufficient to impose some restrictions on cutting. Third, in some parts of the world, in order to meet local needs for wood products which cannot be economically imported from more richly endowed areas, or to make up for the shrinkage of the original tropical forest, intensification of forest management, including high-yielding artificial plantations, may be necessary. This applies particularly to fuelwood and wood for domestic use in the drier areas. Fourth, when the length of the forest fallow becomes too short as a result of the density of the population, shifting cultivation has to be replaced by more intensive land use, including agri-silviculture, which has the dual merit of creating a forest fallow of high commercial value while maintaining a forest cover favourable to the environment. The last three measures mentioned above should be taken in the framework of a proper land use plan.

It therefore seems that up to the year 2000, if only the simple technical solutions that are already well known were to be effectively applied, most of the possible harmful effects could be avoided. During this period, the problem is less technical than social and political, and its solution depends mainly on the determination of the world community and of individual countries.

Beyond the year 2000, however, at least in some parts of the world, more sophisticated and intensive land use methods will have to be employed. Experience shows that a tropical forestry revolution is possible which would allow the developing world to obtain on a sustained basis from more intensively managed forests, whether natural or artificial, the goods and services (including the preservation of the environment) it will need.

In order to take the measures suggested above and to obtain the optimum benefit from their forest potential, both developed and developing countries should accentuate their efforts, in particular at the local community level, in the fields of forest management and planning, forestry research (particularly on the long-term environmental effects of successive rotation of fast-growing tropical plantations), education, extension, and institution building. Forestry education, it should be noted, traditionally includes environmental education as a routine matter.

Problems will be more difficult in the drier areas, where forests are difficult to keep, to establish or to regenerate, and are anyhow of low productivity. This aspect is reviewed later in the discussion of desertification.

WILDLIFE RESOURCES

Many resource surveys fail to recognize wildlife[31] as a significant renewable natural resource, and as a source of food, particularly for rural communities. The distribution of wildlife resources varies considerably both between and within continents. Africa and North America are the richest in quantity and quality, but extensive regions of South America, Asia and Oceania also have wide ranges of fauna. The African fauna is essentially concentrated in savannas and rain forests. In North America and Asia, the tundras contain large stocks of animals, which have a very high potential if managed for food production. South America's tropical rain forests also support a rich fauna, but the quantity is less than in simpler ecosystems such as savannas or tundra.

Table 3-20. Estimates of potential average annual standing crop (biomass) of wild ungulates in principal ecosystems

	...... kg/km^2		
Savannas (Africa)	1,000	to	20,000[1]
Prairies (North America)	2,450	to	3,500
Tundras (North America, North Asia)	170	to	250
Tropical rain forest (South America, Central Africa, Southeast Asia)	1,000	to	3,000
Mountains (Asia, America, Europe)	4,000	to	10,000
Deserts (North America, Asia, Africa)	0.3	to	200
Temperate forests (North America, Europe, Asia)	250	to	1,000

[1] Wide range due to geographic variations within savanna region.

Unproductive ecosystems such as deserts and circumpolar regions have little or no wildlife from the food production point of view. But in other regions with severe limitations for agriculture, wildlife offers a very important alternative use of marginal land. Table 3-20 gives estimates of the biomass potential (meat for human consumption) of the principal undisturbed ecosystems of the world.

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[31] This term is used here to cover all wild animals except fish.

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Table 3-21. Mean annual rural consumption of local and imported animal foods, southern Nigeria, 1965-66

Commodity	Quantity	Share of total consumption of animal products	Value
	thousand tons	%	N£ millions
Game meat 1/	61.7	18.5	10.2
Fish 2/	198.8	59.7	38.2
Poultry and eggs	0.3	0.1	1.0
Dairy products	0.9	0.3	-
Beef, mutton, etc. 3/	71.4	21.4	13.9
TOTAL	333.1	100.0	63.2

Source: Federal Office of Statistics, Rural Economic Survey of Nigeria, 1965-66 - Rural Consumption Enquiry, Food items, West, Mid-West, and Eastern Nigeria, Lagos.

1/ Including rodents and shelled forms; excluding wildfowl,which are not recorded.
2/ Including crabs and crawfish. 3/ Including meat from all domesticated animals except poultry.

Several studies have shown the potential of wildlife for meat production. In the Amazonian forest, for example, the daily per caput game meat consumption of the rural population is 52 to 76 grammes. In southern Nigeria, wildlife accounted for some 19% of animal food consumption, compared with 60% for fish and 21% for domestic livestock (Table 3-21).

In addition to the benefits that wildlife contributes to human welfare in terms of nutrition, there are other valuable products that generate significant cash incomes. These include musk (from the musk deer in Asia), deer antlers (Asia), ivory (elephant and hippopotamus in Africa), luxury leather (e.g. crocodile leather in Africa, Asia and South America), and special wools (e.g. vicuña in Latin America).

Wildlife is also the resource base for recreation and tourism in many parts of the world. This utilization of the resource may be consumptive in the context of recreational hunting, which in many situations can be the most lucrative form of utilization in terms of cash return. In many developed countries, recreational hunting forms an integral part of forest or estate management that contributes to the economic viability of these operations. Utilization may also be non-consumptive, and in many developing countries forms the basis for tourism industries. There are well-known examples of this in Africa, where national park networks have been created that cater for visitors wishing to view, rather than hunt, wildlife.

Depletion of wildlife resources

Statistics on wildlife resources are hard to obtain, but it is known that they are becoming extinct in many regions. For example, there is an almost total absence of wildlife in some parts of the Near East, because of overgrazing and the destruction of the rangelands, following the expansion of human population and domesticated animal production. But it is also due to excessive hunting.

The two main causes of the depletion of wildlife resources are over-exploitation and the destruction of habitat. Over-exploitation results from the uncontrolled commercialization of the products of wildlife, and also from unlawful hunting for personal profit (meat, tusks, skins or antlers). There is also the destruction wrought by irresponsible hunters "for sport" in areas where game laws are either weakly enforced or non-existent.

The depletion or destruction of the habitat becomes acceptable only when organized agriculture can supply more food, more economically, than wildlife would be able to do. Often, however, the destruction of forests and other natural habitats is irrational, and the consequence of migratory agricultural systems or ill-conceived development schemes. As a result wildlife is unable to survive, while the new agricultural system often fails to supply as much food as the wildlife did in its undisturbed state.

The approaches to the conservation and utilization of wildlife resources that appear to hold most promise for the future are adapting traditional systems of use, utilizing the physiological advantages of wild species in harsh environments, and captive breeding to restore wild populations. The adaptation of traditional systems of use is particularly appropriate to the tropical forest areas. The rural populations of these areas are highly dependent on wildlife to meet a significant proportion of their protein requirements. Current work in Ghana and Nigeria on large rodents is an example of this approach. Arid zone and high altitude species have received particular attention in the second approach. Pilot studies on oryx in eastern Africa and on vicuña in Latin America are encouraging. The third approach allows the intensive management of the restored populations, including the farming of the species. Examples include musk deer (for musk), deer (for antlers) and crocodiles (for hides).

FISHERY RESOURCES

With the rapid growth of population and income since the second world war, fishery production has expanded very rapidly. Total landings, including those from inland waters, rose from only 20 million tons in 1948 to over 70 million tons by 1970[32/]. The main trends in production are summarized in Table 3-22, and the recent situation in Figure 3-2, which is appended at the end of the chapter. The recent annual average annual harvest of about 70 million tons contributes 6% of the total world supply of protein, and 18% of animal protein.

Table 3-22. Annual world fish landings

	Annual average									
	1948-52	1953-57	1958-62	1963-67	1968-72	1973-76	1973	1974	1975	1976[1/]
	million metric tons									
Marine waters	19.4	25.2	34.0	46.6	57.5	59.5	56.7	60.4	59.3	61.5
of which										
anchoveta	(-)	(0.1)	(3.7)	(9.0)	(10.0)	(3.5)	(2.0)	(4.0)	(3.5)	(4.5)
other	(19.4)	(25.1)	(30.3)	(37.6)	(47.5)	(56.0)	(54.7)	(56.4)	(55.8)	(57.0)
Inland waters	2.5	3.8	5.8	7.3	8.9	10.3	10.1	10.1	10.4	10.6
TOTAL	21.9	29.0	39.8	53.9	66.5	69.8	66.8	70.5	69.7	72.1

Source: FAO data

1/ Preliminary

Several major influences on the rapid growth of fishery production may be identified. These include the expansion of production by Japan by means of both local and long-distance fishing, increased long-distance operations by the U.S.S.R. and other centrally planned economies, and the explosive growth of the anchoveta fishery in the southeast

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[32/] FAO, Review of the State of Exploitation of the World Fish Resources, COFI/77/5, Rome, 1976.

Pacific. In particular, fluctuations in the catch of anchoveta and other shoaling pelagic fish used largely for reduction to meal and oil have had a marked effect on the level of world fishery production. They sharply boosted the rate of increase during the 1960s and caused it to level off in the 1970s as catches declined because of heavy fishing and environmental changes. The present prospects for the recovery of several of these stocks, including the anchoveta, are poor until at least the 1980s. Some increase in the catch of fish used for direct human consumption can, however, be expected, particularly in the developing countries.

Table 3-23 indicates the relative magnitude and degree of exploitation of the fish, crustacean and cephalopod resources of the major marine areas. Molluscs other than cephalopods (oysters, mussels, clams, etc.) have been excluded, since their potential (which is ultimately very large) depends more on cultivation than on natural factors affecting self-renewal. The data in the table must, however, be interpreted with some caution. For example, the apparently large unexploited potential in the southeast Pacific and northwest Atlantic is to some extent illusory and results from overexploitation. Catches in these areas have in the past been significantly higher than in 1975.

The table indicates heavy exploitation of areas close to developed countries (e.g., northwest Pacific, northeast Atlantic and the Mediterranean). The best possibilities for greater catches are in tropical or sub-tropical waters (e.g., the Indian Ocean) off the coasts of developing countries. In the world's oceans as a whole, roughly half of the potential remains theoretically unexploited. However, given the practical impossibility of harvesting the full potential of all stocks, the possibilities of catch increase are considerably less than this. Probably no more than an additional 30 to 35 million tons of

Table 3-23. Catches and potential production of marine fish, crustaceans and cephalopods by major marine area

	Catch					Estimated potential	Utilization 1975
	1965	1970	1972	1974	1975		
	.... thousand metric tons				....		...%....
N.W. Atlantic	3,242	3,697	3,833	3,461	3,230	7,000	46
N.E. Atlantic	9,090	10,140	10,045	11,222	11,499	14,600	79
W.C. Atlantic	1,192	1,208	1,298	1,334	1,350	6,400	21
E.C. Atlantic	1,216	2,981	3,350	3,758	3,493	5,600	62
Mediterranean and Black Sea	940	1,040	1,077	1,305	1,236	1,800	69
S.W. Atlantic	489	1,032	774	886	824	8,500	10
S.E. Atlantic	2,213	2,453	2,954	2,876	2,535	5,000	51
W. Indian Ocean	1,238	1,583	1,737	2,141	2,029	9,600	21
E. Indian Ocean	628	779	799	1,010	1,042	5,300	20
N.W. Pacific	9,540	11,634	13,061	14,825	15,201	17,400	87
N.E. Pacific	1,420	2,609	2,725	2,293	2,206	4,600	48
W.C. Pacific	2,560	3,923	4,505	4,867	4,637	10,400	45
E.C. Pacific	575	861	923	1,023	1,233	6,000	21
S.W. Pacific	101	144	249	396	258	1,300	20
S.E. Pacific	8,054	13,621	5,445	5,232	4,516	13,300 1/	34
TOTAL	42,498	57,705	52,775	56,289	55,289	116,800	47

Source: FAO, Review of the State of Exploitation of the World Fish Resources, op. cit.

1/ Assuming full recovery of anchoveta stock.

Table 3-24. State of exploitation of fish stocks in the northeast Atlantic

Stocks	Estimated potential	1974 catch	State of exploitation[1]
	..... thousand metric tons		
Cod[2]	1,175	1,235	3
Haddock[2]	300	360	3
Hake	150	98	3–4
Saithe	700	678	3
Blue whiting	1,000	31	1
Sandeels	500	532	2
Capelin	1,500	1,610	2–3
Herring[2]	2,200	259	4
Sprat[2]	600	555	2
Pilchard	400	136	2
Mackerel[2]	400	326	3
Squid	1,000	9	1

Source: FAO, Review of the State of Exploitation of the World Fish Resources, op. cit.

1/ The figure 1 indicates that the stock is virtually unexploited, 2 that it is moderately exploited, 3 fully exploited, and 4 depleted. – 2/ Selected stocks only.

conventional species can be harvested on a sustainable basis. Since the unexploited potential consists largely of species of poorer commercial prospects than those already harvested, in the absence of any major new developments the average growth of production is unlikely to exceed 1 or 2% a year.

As a more detailed example, the size of catches in relation to the estimated potential is shown in Table 3-24 for major species in the northeast Atlantic. This confirms that all the larger bottom-dwelling fish are fully exploited, and that all herring stocks have been seriously depleted. This applies especially to the Atlanto-Scandian stock, where the fishery for adult fish has ceased to be viable. Some of the stocks are protected by national regulations, while control over the fishing of others is the subject of negotiations both within the European Economic Community (EEC) and between the EEC and third countries. For the depleted North Sea herring stock, a complete ban on fishing was introduced in August 1977.

For the northwest Pacific, estimates of potential are less detailed. Sardine is regarded as moderately exploited and salmon somewhat depleted, but all the other major stocks are classified as fully exploited.[33]

The years 1975-76 marked a milestone in world fisheries as the final era of relatively unrestrained high seas fishing (with the exception of tuna). Though the discussions at the United Nations Conference on the Law of the Sea have not reached final conclusions, *de facto* extensions of jurisdiction by most countries with large fisheries off their coasts had taken place by 1977. The likely impact of this extension of waters under national jurisdiction can be seen from Table 3-25, which gives for each fishery region rough estimates of the total catch, excluding whales, taken by non-coastal countries, as well as the division of this total between vessels from developing and developed countries.

33/ Ibid.

Table 3-25. World fish catches by non-local fleets, 1972[1]

Region	Catch		Origin of vessel		Location	
	All species	Tuna	Developed countries	Developing countries	Off developed countries	Off developing countries
	.... thousand metric tons					
N.W. Atlantic	2,292	10	2,288	4	2,194	98
N.E. Atlantic	3,667	1	3,667	-	3,619	48
W.C. Atlantic	143	5	128	15	37	106
E.C. Atlantic	1,930	180	1,870	60	-	1,930
Mediterranean and Black Sea	40	-	40	-	-	40
S.W. Atlantic	24	12	14	10	-	24
S.E. Atlantic	1,771	29	1,662	109	271	1,500
W. Indian Ocean	221	67	158	43	-	201
E. Indian Ocean	88	36	23	65	9	79
N.W. Pacific	2,936	-	2,600	336	2,550	386
N.E. Pacific	2,254	-	2,254	-	2,254	-
W.C. Pacific	479	114	129	350	-	479
E.C. Pacific	287	274	284	3	13	274
S.W. Pacific	199	100	123	76	199	-
S.E. Pacific	43	13	48	-	-	48
TOTAL	16,359	841	15,288	1,071	11,146	5,213

Source: FAO, Review of the State of Exploitation of World Fish Resources, op. cit.

[1] Excluding catches by countries in areas off their own coasts.

The extent to which fishing by non-coastal countries has been concentrated in the North Pacific, the North Atlantic and the Eastern Atlantic is evident. The effects of the extension of fishing limits in these areas are likely to be substantial.

The expansion of world catches of fish from inland waters has slowed down markedly during the past five years (Table 3-26). They have accounted for about 15% of all reported catches in most recent years. Many inland waters are now fully exploited, and in some parts of the world it is doubtful whether there can be much further growth in catches from natural stocks.

Inland catches may be of great importance at the local level. They are particularly significant in Asia, and to a smaller extent in Africa. The greatest potential for increasing catches from natural inland waters probably lies in Latin America. Aquaculture, which is discussed separately below, is reported to contribute a large proportion of total inland catches in Asia, especially in China, but the lack of precise data makes the interpretation of reported catches difficult.

Problems of living aquatic resources

In the context of natural resources and the human environment, the main problems of living aquatic resources that have to be considered are overfishing (including the special problem of marine mammals), and the effects of potentially polluting materials.

The effects of the relatively high degree of exploitation and, in some cases, depletion of certain fish stocks have already been mentioned. It is essential that there should be a balance between the size of catches and the size of stocks. Although the concept of maximum sustainable yield is useful, it has to be carefully interpreted because of various

Table 3-26. World fish catches in inland waters

Region	1965	1970	1971	1972	1973	1974	1975
	.... thousand metric tons						
Africa	820	1,140	1,366	1,410	1,424	1,442	1,498
North America	140	140	128	131	146	153	153
South America	230	250	135	189	194	169	171
Asia	5,400	6,250	7,068	7,128	7,203	7,267	7,393
Europe	210	230	240	251	260	266	285
Oceania	-	-	3	3	2	6	11
U.S.S.R.	830	850	935	870	850	773	944
TOTAL	7,630	8,860	9,875	9,982	10,078	10,076	10,444

Source: FAO data.

complicating factors. Nevertheless, for any stock of fish, there is a level of fishing beyond which the stock does not produce any sustainable yield increase. At this point, further fishing can result in a decrease in yield, so that it is essential to limit the size of catches before this point is reached.

Until the recent general de facto extension of limits referred to above, fisheries management was largely the responsibility of international bodies, such as the Northeast Atlantic Fisheries Commission. Such bodies generally achieved only limited success in this task. Although the trend to extended jurisdiction will allow greater participation by coastal states in the fisheries, it will also impose the management duty of adjusting fishing effort to the stocks available. Where migratory stocks are concerned, this will still often involve some form of international negotiation, but the reduction in the number of participants in many of the international commissions may make agreement easier to obtain.

Various species of marine mammals (whales, seals, dolphins and dugongs) are being exploited or otherwise affected by human activities. Some species have been brought close to extermination and some (Steller's seacow, the Western Pacific gray whale, and perhaps the Caribbean monk seal) are actually extinct. Other species have been seriously reduced, such as the blue humpback and fin whales. Most of the seriously depleted species are now under protection. Various species or sub-groups, such as the Californian gray whale, the sea otter and the southern sea elephant, have made good recoveries under protection.

The effects of potentially polluting materials on aquatic production were reviewed in detail in the 1971 issue of The State of Food and Agriculture.[34] The conclusions reached at that time are still valid, and only some of the main aspects will therefore be referred to here.

The principal aquatic pollutants are domestic sewage and agricultural wastes, detergents, pesticides, oil and oil dispersants, other organic wastes, inorganic wastes, radioactive materials, and solid wastes. All these substances have deleterious biological and ecological effects on aquatic resources, as well as direct effects on fishing and fishery products, especially in inland and coastal waters.

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[34] FAO, The State of Food and Agriculture 1971, Rome, 1971, p. 121-170.

Developed countries are obviously the largest producers of pollutants affecting fisheries. In many developing countries, however, especially in southern continental Asia, fishing in lakes and streams is of considerable importance. The problems of water supply and the management of its quality for fisheries are immense in these countries, and in many instances the use of water for fisheries must be coordinated with domestic, industrial, and irrigation and other agricultural uses.

There are many ways of reducing the pollution of fisheries and of introducing preventive and curative measures. The integrated planning of fisheries, agricultural and industrial development schemes is necessary in order to recycle their waste products into useful functions. Emergency remedial measures are often necessary, as well as administrative and legal controls, and the establishment and strengthening of research institutions.

Aquaculture

Although the world fishery catch is still increasing, the trend of growth seems, as noted above, to be levelling off. Greater attention is therefore being given to aquaculture as a further means to increase food production from aquatic living resources. Although good statistics do not exist, the aquaculture production of the world is estimated to be over 6 million tons, or somewhat less than 10% of the world total fishery output.35/ About two thirds of the aquaculture production is fin fish, and the rest mainly molluscs and seaweeds. About 80% of the total comes from the developing countries in Asia, where (except in China) production is dominated by small-scale individual farmers. Achievements elsewhere, as in Europe and America, have tended towards systems needing larger investments, and have concentrated on high-priced species.

Technological advances in aquaculture production in the last decade have shown that it could still be greatly increased. It is no longer limited to specially constructed ponds but can be carried out in natural waters, both inland and coastal. Cage and pen culture are outstanding examples of recent technologies that have evolved in some countries. "Raceways" and "silos" have been developed as a new system. Aquaculture combined with agricultural activities has been found to be a very effective means of converting organic wastes into useful products for human food.

The potential for the expansion and development of aquaculture is great, particularly in the developing countries. It could produce a large amount of additional animal protein. Among the main problems are the limited supply of water in some areas, the deteriorating quality of water, particularly in highly industrialized areas, difficulties in securing sufficient amounts of seeds, and the high price of feeds, fertilizers and other inputs.

GENETIC RESOURCES

The plant or animal breeder, in effecting genetic improvement, is strongly guided by concepts of biometrical genetics, whereby the complexities of continuously varying quantitative characters are studied in order to select those that can be easily exploited. The selection of the best parents and methods often starts from a survey of the genotypically and environmentally determined variation in the genetic stocks available.

New strains of animals, plants, fish and even micro-organisms are constantly being developed in response to the needs of modern intensive production systems. Because of intense selection for high performance, many recent varieties and breeds possess a narrow genetic base. In the past, wide genetic diversity was maintained and often evolution continued by dynamic interaction with wild relatives. Innumerable strains and races developed to suit different local environments, especially in some areas which represent centres of diversity. Many of these primitive forms are now at risk because of modern intensive agricultural practices, and even forest, wildlife and other species are threatened by environmental management and modification. The loss of genetic

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35/ FAO, Report of the Technical Conference on Aquaculture, Kyoto, Japan, 26 May - 2 June 1976, FAO Fisheries Report No. 188, Rome, 1976.

diversity threatens future breeding and hence future development. Although short-term development will rely on the selection and exploitation of modern high-yielding and high-quality stocks, longer-term development may well need to revert to the genetic diversity that still exists. If this is not collected, documented, conserved and used, it will be eroded and become irreplaceable.

Crop genetic resources

For the past decade, FAO has played a central role in taking and stimulating action to collect, conserve, evaluate and document crop genetic resources. Plant breeders have become increasingly aware that unexploited genetic diversity should not be abandoned, and that progress in plant breeding requires a continuous supply of genes or gene-complexes to meet present and unforeseen needs.

Rapid changes in agriculture, and especially the trend to greater uniformity in crops, has in several cases led to genetic vulnerability and crop losses in newly released varieties. It is in the interest of every country to maintain genetic diversity to provide maximum protection against such crop production losses, so that technological advances in crop yields or quality can continue and the diversity provide protection against any perceptible genetic change in the prevalent pests and diseases. Surveys of most existing national collections show that, although many have sufficient coverage of elite cultivars, mutants and commercial varieties, they are mostly deficient in primitive cultivars, weed races and closely related wild species, all of which are usually rich in gene combinations for adaptability. This material can be manipulated to maximize potential gains, and wide crosses can be used on a larger scale, including the theoretical possibility of very wide DNA hybridizations.

In 1972 the United Nations Conference on the Human Environment made several recommendations on genetic resources, including the need to organize a coordinating body. The International Board for Plant Genetic Resources (IBPGR) was thus established in 1974, with the sponsorship of the Consultative Group on International Agricultural Research (CGIAR), and a secretariat provided by FAO. There have also been a number of regional initiatives.

International and national awareness have increased, and many countries have established national genetic resources committees. Through its Crop Germplasm Advisory Committees for a number of major crops, the IBPGR provides advice on establishing world networks dealing with the collection, conservation, documentation and use of the crop germplasm. National programmes are increasingly participating in regional cooperative efforts. FAO and the IBPGR have recommended standards for long-term seed conservation, and for the engineering and design aspects of seed storage facilities. The IBPGR has started to designate institutions to be responsible for maintaining the world's major base collections of seeds of the principal food crops for long-term conservation. Expanded training programmes are being supported to provide personnel in the developing world for genetic resources work. FAO and the IBPGR have jointly sponsored the development of an international computerized system for recording data about genetic resources. Priorities have been established for the collection of crops and also for work in the areas showing significant genetic diversity.

In spite of these important achievements, it is still necessary to stimulate many countries to develop national crop genetic resources programmes. While initially the stress should oontinue to be on the collection and conservation of the material, the programmes must be integrated with all aspects of genetic resources work, in order to derive full benefit from the use of the material.

The collecting of crop genetic resources must be rapidly intensified, in order to keep pace with the eroding away of endemic variability which is occurring in the developing countries. Whereas international bodies will be more and more concerned with rescuing variability which is threatened, the national programmes will need to implement plans promptly to collect and conserve the major food, feed and fibre crops, and participate internationally in a global network.

The material collected and conserved has to be evaluated for a number of characteristics. Following evaluation, a broad array of plant breeding programmes should successfully exploit the genetic resources. This will also make it possible to pursue greater crop diversity and the development of varieties for crop production in marginal areas.

Forest genetic resources

In contrast to crop production, forestry is still largely concerned with "wild" species. It is estimated that only about 80 million ha of man-made forests had been planted up to 1965.[36] Over half the planted forests at that time were less than ten years old. Forestry is now where agriculture was about ten thousand years ago. Wild populations predominate, but there are some primitive cultivars of considerable promise in most countries. There are therefore good opportunities to conserve genetic diversity as part of the conservation of natural forest ecosystems.

Operations undertaken in the last few decades in exploration, collection and evaluation have conferred incidental benefits in conservation. The current FAO/UNEP project for the Conservation of Forest Genetic Resources is directed specifically towards conservation for its own sake, and includes action for the conservation of genetic resources *in situ* as a part of natural ecosystems, as seed, and in artificial stands *ex situ*.

A major problem is the lack of knowledge of the reproductive biology of many tree species. Even now, only a few of those planted as commercial species have been studied in any detail. The breeding systems and seed physiology of tropical moist forest species present a special problem, since the seed viability of many of them is short, so that the techniques of drying to a low moisture content and storing at low temperatures, which are standard for "orthodox" seeds, are unsuccessful.

Especially in the tropics, there is a risk that, before a rational breeding programme can start, certain populations will have been lost as a result of pressure to divert the land carrying natural stands to some other purpose. Though the risk of entire commercial species becoming extinct is small, certain populations are known to be under threat. In the case of the climax forests of the humid tropical zone, the conservation of a large number of valuable species depends heavily on the continued integrity of the ecosystem to which they belong.

Tree breeding provides the possibility of increasing genetic diversity through the controlled production of new gene combinations. It also carries the risk of reducing genetic diversity, through the mass propagation of a narrow range of "improved" genotypes, but this can be mitigated by a well-planned breeding strategy.

During the last decade the biggest progress has been in the exploration and collection of seed from a number of sources covering certain important commercial species. This has made it possible to carry out international provenance trials over a wide range of climates and sites in many countries, and thus to investigate which provenances are of most general value over a wider range, and to estimate the extent of genotype and environment interaction, the importance of which varies greatly from species to species and provenance to provenance. Another line of research which may give valuable results in the future is concerned with the separation and identification of seed resources by biochemical methods, e.g. using phenols and iscenzymes. In many older species and provenance trials the exact source of the seed is unknown, and such biochemical methods may make possible the identification of provenances which have done particularly well in these older trials.

There is now greater realization of the need for the dynamic management of natural ecosystems and the genetic resources they contain for the purpose of conservation, rather than a static "museum type" of preservation. The concept of a central core, surrounded by one or more buffer zones, allows the flexibility which is necessary if conservation is to be integrated with development.[37]

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[36] FAO, Report on World Symposium on Man-Made Forests, *Unasylva*, 21, 1967, p. 3-4.

The implementation of the FAO/UNEP project for the Conservation of Forest Genetic Resources has made it possible to initiate the establishment of ex situ conservation stands (each of approximately 10 ha) of important commercial species which are suitable for plantation monoculture. Ideal species for this purpose are pioneers such as some of the pines and the eucalypts. Ex situ conservation enables genetic resources to be conserved in reasonably accessible locations, where it is possible to exercise close management and protection which is impossible within the natural range.

Other developments are concerned with the possibilities of long-term storage of seed. For "orthodox" seeds, the methods recommended by agricultural seed specialists seem to be equally applicable to forest seeds. In some cases of species difficult to store, careful attention must be paid to the handling and drying of the seed between collection and storage. For "recalcitrant" seeds, the situation is much more difficult, but again the problems are similar for both forest seeds and agricultural seeds. Much more research needs to be done on some of these seeds, particularly those of tropical species. Tissue and organ culture is a new possibility and more research may well indicate that it is a practical means of long-term conservation. In tree breeding, the ability of the geneticist to bring together genotypes which would not normally interbreed in nature has made it possible to achieve substantial genetic gains, combined with a reduction in the costs of harvesting the seed. In some cases, high specific combining ability of two individual genotypes has shown itself to be much more significant for breeding than the general combining activities of each one. The artificial creation of new combinations of gene should be considered just as important as the conservation of the natural genetic resources.

Animal genetic resources

Whereas the number of plant species of actual or potential use in agriculture is comparatively large, 90% of domestic livestock belong to only a dozen species. However, within each species there are very many breeds or strains which by natural and man-directed selection have become adapted to a variety of environments, climates and production systems. The genetic variation existing between as well as within breeds or strains forms the basis for adaptation to new situations as well as for future increases in animal productivity.

For the utilization and conservation of animal genetic resources, simultaneous consideration must be given to the immediate need for genetic improvement and to conservation for future unforeseen needs (as well as for historical and scientific purposes). Although there is an understandable tendency to stress the immediate needs, it is becoming increasingly recognized that concerted action is needed to evaluate locally adapted breeds and strains and to conserve useful animal genetic stocks for present and future needs so as to avoid further irrevocable losses.

The introduction of artificial insemination has revolutionized the scope of animal breeding, particularly with cattle, where frozen semen is widely used. Efficient methods have been developed for genetic evaluation (progeny and performance testing) and intensive selection, and are now widely used in conjunction with artificial insemination. In the industrialized countries, the increase in the genetic potential and productivity of practically all livestock species has been very marked during the last 25 years, but the same methods are also becoming well established in developing countries. Because of these new breeding methods, more change in the livestock populations can now take place in a few decades than occurred over hundreds of years in the past.

37/ UNESCO, Criteria and Guidelines for the Choice and Establishment of Biosphere Reserves, Man and the Biosphere Report No. 22, Paris, 1974.

Breeds or strains that are considered less competitive disappear rapidly in the industrialized countries. Of the total number of cattle breeds which existed in 1970 in Europe and the Mediterranean basin, 115 indigenous breeds are threatened by extinction and only 30 are holding their own.[38] Most of the changes have been based on logical efforts to change the cattle population towards more efficient animals which would respond to the general improvements in agriculture and to changes in market requirements. However, as the changes are so rapid, and since the loss of a breed is irrevocable, it is necessary to decide in time what breeds should and could be preserved for future economic needs or for cultural or scientific reasons.

With regard to dairy production in the developing countries, numerous studies have shown that crossbreeding and upgrading to specialized dairy breeds from the temperate zone lead to a rapid increase in milk production. In areas with moderate climate (e.g., the high plateaus of Iran and Kenya) and reasonably good management, the native breeds may very well be entirely replaced by temperate dairy breeds or high grades thereof. However, where the climatic stress is severe, as in the humid tropics, and management practices are lagging, crossbreds between native and temperate breeds are superior. Because of the excellent results obtained in the developing countries with the first cross and generally also with the first backcross to temperate breeds, there has been a tendency to ignore native cattle for milk production. However, as heterosis (hybrid vigour) is large, and genetic tolerance to climatic stress can be provided by genes from tropical cattle, the use of some kind of criss-cross system between temperate and improved tropical breeds seems to be called for in the hot humid tropics. The main problem is the low genetic potential for milk production of most breeds originating in the tropics, although there are a few notable exceptions, such as the Sahiwal, Tharparker and Red Sindhi breeds of India and Pakistan, the Kenana and Butana of the Sudan, and some Criollo strains in Latin America. Unfortunately, these strains are low in numbers, and programmes for their genetic improvement are often weak. It is important that they should be preserved and further developed, as with the successful initiatives in Kenya to improve the Sahiwal population through a modern breeding programme.

Considerable improvement of the natural environment (shade, improved pastures, supplementary feeding, etc.) is usually undertaken for dairy production, but beef cattle have to a much larger extent to cope with the existing environment, and are kept on land which cannot be used for more intensive types of agricultural production. The most important production characteristic for beef cattle is the ability to survive, grow and reproduce, and the inherent hardiness of the local strains is therefore a great asset. Under unimproved and moderately improved conditions, the local strains do better than imported breeds, although where the pastures are improved and reasonably good veterinary services available, crosses between European cattle and Boran, or other African zebus, are superior to the pure zebu strains. Beef production in the developing countries will therefore have to rely to a large extent on the local well-adapted strains, and it is important that these should be systematically evaluated and the better ones included in programmes for further genetic improvement.

In Africa the single most important constraint to cattle production is the prevalence of trypanosomiasis in large areas. In cooperation with the International Livestock Centre for Africa (ILCA) and UNEP, FAO is undertaking a survey of trypano-tolerant cattle breeds in West Africa, followed by breeding programmes to ensure their conservation (e.g. Lagune cattle) or better economic exploitation (e.g., Baulé and Borgu). The N'Dama and West African Shorthorn, after generations of natural selection, have acquired varying degrees of tolerance to trypanosomiasis, but the genetic nature of the tolerance and the general characteristics of trypano-tolerant strains are very poorly known. Such animals should be studied, evaluated and protected against indiscriminate crossing, in order to avoid the loss of a genetic resource that might be of considerable importance in the future.

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[38] J.J. Lamargne, 'Disappearing cattle breeds in Europe and the Mediterranean basin,' FAO/UNEP Pilot Study on Conservation of Animal Genetic Resources, Rome, 1975, p. 21-41.

The problems of sheep breeding in the developing countries are in many ways similar to those for beef cattle, although sheep are usually kept under even more extreme environmental conditions. Local sheep breeds show a high degree of adaptation to existing environmental conditions. The low lambing rate of most sheep breeds is a general handicap, but in several tropical areas, and particularly in the Caribbean, Indonesia and West Africa, there are highly fertile hair sheep breeds. The best known is the Barbados Blackbelly, but its numbers are few and, in spite of its reputation, there are few published figures on its fertility and other performance traits. It is high time that this and other prolific tropical sheep should be systematically evaluated.

In the industrialized countries highly productive strains of pigs have been developed, with low feed requirements per unit of output. The pigs native to the tropical countries are usually slow growing and produce a high portion of fat. Most pig breeds and strains thrive well in warm climates, provided they are kept under hygienic conditions. Thus the adoption of intensive production systems in the developing countries has been accompanied by the introduction of the high-yielding breeds of the developed countries. In these circumstances, no great efforts seem to be required to adapt the pigs through selection to new and very different environments. However, several of the local pig strains in the tropical countries are likely to disappear, because of their low competitiveness under more intensive production systems, and efforts should be made to maintain some of these in animal parks and institutions.

Poultry production in the industrialized countries has undergone even more dramatic changes than pig production. Most breeding stock is now produced by large companies, utilizing scientific breeding techniques. The old breed concept has been abolished, and the commercial strains usually contain genes from several sources, although in laying birds the Leghorn component is usually large. The production birds are as a rule derived by crossing at least four lines, so as to ensure hybrid vigour. In the developing countries the commercial sector of large-scale intensive production is based on continuous and costly imports of breeding material (grandparent stock) from large enterprises in Europe or North America. As the standards of feeding, housing and management are likely to continue to lag for some time, and as there appears to be a considerable genotype-environmental interaction for overall productivity, it is time to reconsider such import policies. India, for example, has announced that it will soon discontinue imports of breeding stock. In an industry that is changing as rapidly as poultry production, it is very difficult to pinpoint which genetic strains require conservation for possible use under a future, new set of conditions. That there is a conservation problem under the modern poultry production systems is, however, recognized by many scientists and also by commercial breeding companies, some of which keep reserve stock for future use. More needs to be done, particularly in the developing countries.

There are a number of livestock species, mainly confined to the developing countries, which have been grossly neglected as far as genetic evaluation and improvement is concerned. For example, in spite of the considerable importance of the goat as a source of milk, meat, hair and hides, and its adaptability to a wide variety of natural conditions from semi-arid highlands to lowland tropical forests, very little is known about the relative economic merit of different strains and breeds, and even less has been done to introduce modern improvement methods. At present there seems to be no pressing need for conservation programmes, but some attention to the evaluation and better utilization of the goat is obviously required.

Most of the draught power used in rice cultivation in the Far East is provided by water buffaloes of the swamp type, and in India about three quarters of the milk produced for human consumption comes from water buffaloes of the so-called river type. In India and Pakistan buffaloes are increasing more rapidly than cattle, which indicates their competitiveness. Their meat is also becoming more appreciated. A more thorough evaluation may indicate whether specific steps should be taken to conserve special breeds for future use in breeding programmes. At present, however, there is no serious problem of genetic deterioration.

Camel meat is much appreciated in several north African and Near East countries, and the camel is therefore increasingly being used as a meat animal on poor rangelands. There is very little information on its potential as a milk and wool producer, or on the specific needs for conservation.

The camelidae of Latin America are confined to the Andean highlands. There are two domestic species, the alpaca and the llama, which are used for the production of meat and wool and as beasts of burden, and are of great importance to the economies of some of the Andean countries, notably Peru and Bolivia.

As it will be difficult to conserve all the breeds and strains of domesticated animals now in existence, careful decisions are necessary, nationally and internationally, which should take into account the often limited knowledge available on future needs. The most appropriate method for the conservation of breeds seems at present to be through animal parks. Relatively small samples of animals are required, but the initial animal population must be very carefully selected. Thereafter, the maintenance of the herd requires a thoroughly planned breeding programme to minimize random genetic drift. Increased international cooperation is called for between scientists and organizations responsible for such animal parks.

With scientific progress, other methods might be developed to complement or partly replace the rather expensive method of conservation in animal parks. The preservation of genetic material in the form of deep frozen semen is one possibility that is already used to a certain extent in cattle. Semen from a group of 10 to 20 well-chosen bulls will make a fairly good sample of a breed. It has also proved possible to conserve living mammalian embryos in the frozen state, and for brood cows that have received embryos conserved in this way to give birth to normal calves.

For some time to come, however, genetic conservation will have to be through more traditional breeding methods. It will be necessary to keep a sufficiently broad genetic base in the farm animal populations to make it possible to achieve gradual changes through selection to adapt the breeds and strains to different environmental or economic situations as they arise. There is obviously a conflict between the demand for rapid genetic progress in productivity under a set economic situation, and the demand to keep genetic flexibility for future unknown needs. How to obtain the best balance between these two demands requires further study.

Wildlife genetic resources

Although the world has already lost many species of wildlife, many more are at present endangered: over 1,000 species or subspecies of vertebrate animals are threatened with extinction. Their conservation *in situ* causes problems because of their mobility. Many of these wild species are adapted to harsh environments, and they thus constitute a genetic resource of great value.

The conservation of wild animals *ex situ* is practised in zoological gardens, wildlife parks, game farms and the like. Some species can survive this way even if *in situ* conservation is unsuccessful. However, genetic adaptation to an unnatural environment, and a break in the continuous process of evolution through natural selection in the wild population, may destroy the value of the genetic resource itself.

The main problem in the conservation of wild animals *in situ* lies in the conservation of sufficient areas of their habitat. Migratory animals are a particularly difficult case in this respect. In contrast to domestic animals, their management by man has received little attention. Their seasonal and daily movements for water, food, shade and breeding often require large areas with diversified habitats. If their conservation is to be successful all these aspects need to be considered.

Fish genetic resources

Aquaculture has been going on for centuries, and yet very little is known of the genetic qualities of the culture species used. Fish transplantation and hybridization is being carried out with more and more intensity, but without any control or organization. As a result, the original strains used in aquaculture have been lost. Introductions or exotic species upset the genetic advantage of local populations for natural selection. With the exception of carps and some salmonids, the genetic quality of species with potential for aquaculture is not known. Exploitation of natural stocks could lead to reduction in species and in genetic variation.

The major gap is therefore the lack of information. A catalogue of genetic materials, which would serve as a nucleus for conservation efforts on a worldwide basis, does not exist.

ENVIRONMENTAL IMPACT OF INTENSIFICATION OF AGRICULTURE

The above survey of the state of natural resources for food and agricultural production has drawn attention to the many ways in which the intensification of production has led to the degradation and depletion of these resources. In addition, some aspects of the intensification of agriculture and of related forest and agro-industries may create specific pollution problems in the environment. The problems arising from the use of fertilizers and pesticides and from forest industries are briefly reviewed below. There is also a brief discussion of the contamination of food and feed from various sources.

Another problem arises from the use of agricultural and agro-industrial wastes and residues. A recent UNEP/FAO seminar which reviewed the global availability of such materials for recycling concluded that it was difficult to identify the extent of pollution or environmental problems deriving from them.[39/] A review of this subject must therefore await the analysis of the data that are at present being collected, although some mention is made below of the problems involved in the use of these and other organic materials as fertilizer.

FERTILIZER USE

Especially in view of the very rapid increase in the use of mineral fertilizers, concern has been expressed about the possible side-effects of intensive fertilizer use on the environment. Because of the crucial importance of effective fertilizer use for the expansion of food production,[40/] it is essential to examine the grounds for these fears.

The world consumption of mineral fertilizers has quadrupled during the last two decades, increasing from about 22 million tons of plant nutrients (N, P_2O_5 and K_2O) in the early 1950s to 89 million tons in 1975/76. However, although there is intensive use in developed countries, consumption remains low in the developing world. The total consumption in all of the developing countries taken together (including China and the other Asian centrally planned economies) is approximately equal to that in North America alone.

In a recent study of the effects of intensive fertilizer use on the environment in countries where consumption is steadily rising,[41/] it was concluded that, when

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[39/] UNEP/FAO Seminar on Utilization and Management of Agricultural and Agro-Industrial Wastes, Rome, 18 - 21 January 1977.

[40/] It will be recalled that Table 3-1 indicated that about 23% of world soil resources suffer from mineral stress, with proportions as high as 59% in southeast Asia, 47% in South America, and 33% in Africa.

[41/] FAO/SIDA, Effects of Intensive Fertilizer Use on the Human Environment, FAO Soils Bulletin No. 16, Rome, 1972.

fertilizers are properly applied, their contribution to the loading of surface and groundwater in nitrogen, phosphorus and potassium is smaller than that coming from other sources. Where detrimental effects were observed, they were related to excessive use, and could be corrected by the careful adjustment of applications to the requirements of soils and plants. On the other hand, the efficient use of fertilizers can also benefit the environment indirectly in that, by increasing the yield per hectare of good land, it allows the withdrawal from cultivation of land of low inherent quality that otherwise would be prone to such hazards as erosion.

Since not all the nutrients applied are taken up by the crop, the fate of fertilizer residues must be given due consideration. They can remain in the soil, be removed in drainage water, or be lost to the atmosphere by volatilization. The three major crop nutrients behave quite differently under intensive use in soils.

Only a negligible proportion of fertilizer phosphorus is leached from soils into drainage water, since it is very immobile in most soils. It can, however, be carried into rivers, mainly through soil erosion, having first been absorbed on soil particles. Similarly, only a small proportion of fertilizer potassium can be lost by leaching, because most soils hold most of the added potassium sufficiently strongly for only very little to enter the soil drainage water.

Nitrogen is the most likely fertilizer element to be leached out of the soil, but there is very limited evidence that this has had an appreciable effect on the composition of groundwater or streams. Researchers recognize, however, that it is technically difficult to interpret specific ohanges in water composition, since the whole process is complicated by related biological activities and the release of various other industrial, urban and rural effluents in the drainage system. Run-off and soil erosion can be a main factor in the enrichment of surface waters in plant nutrients, especially where steeply sloping lands are cultivated. The intensive use of fertilizers should therefore be combined with proper soil conservation practices.

Recent research results indicate that nitrogen oxide (N_2O) released into the atmosphere through a number of man's activities can be carried by air motions into the stratosphere, and contribute to the depletion of the ozone layer. The denitrification of nitrogenous fertilizers used for intensive cultivation is often mentioned as one of the causes. A recent UNEP expert meeting, however, came to the conclusion that more research is needed to identify those human activities contributing most to the release of N_2O in the atmosphere.42/

Possibly undesirable effects on the environment will be minimized if fertilizers are used with maximum efficiency. The correct choice of fertilizers and their application at the correct time and in optimum quantity for crop yields are all important considerations. In most developing countries, the threshold at which fertilizer applications would be in excess of actual requirements is far from being reached. At present only 15% of the total world consumption of mineral fertilizers is used in developing countries, although they have 70% of the world population. There is still plenty of room for the further intensification of fertilizer use in these countries.

The constraints on the increased use of fertilizers in the developing countries are well known. They include the lack of fertilizer supplies at national or village level, lack of knowledge among small farmers, low prices for farm products, high fertilizer prices, and the shortage of credit facilities. Under these circumstances, any fear of a negative impact of fertilizers in these countries is premature.

Organic fertilizers

Organic materials represent a rich and underexploited source of fertilizer, especially in the developing countries. It is estimated in Table 3-27 that about 113 million

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42/ UNEP, Meeting of Experts Designated by Governments, Inter-Governmental and Non-Governmental Organizations on the Ozone Layer, Washington, D.C., 1 - 9 March 1977.

Table 3-27. Availability of plant nutrients in organic residues in developing countries[1/], 1971

Source	N	P_2O_5	K_2O	Total
	....	million metric tons	....	
Human	12.3	2.9	2.6	17.8
Cattle	11.4	3.1	9.0	23.5
Farm compost	9.5	3.3	9.5	22.3
Urban compost	0.5	0.4	0.6	1.5
Urban sewage	1.4	0.3	0.9	2.6
Other[2/]	6.6	4.5	11.4	22.5
TOTAL	41.7	14.5	34.0	90.2

1/ Excluding central America and developing countries in Oceania, but including Asian centrally planned economies. – 2/ Bone meal, poultry, sheep and goat litter, bagasse, oil cake, press mud.

tons of plant nutrients were potentially available in these countries in 1971 in the form of organic residues. This is about eight times the 13.5 million tons of mineral fertilizer used in the same countries in 1970/71. This enormous potential supply of organic plant nutrients in the developing countries also considerably exceeds the present total world supply from mineral fertilizers. In combination with the limited amount of mineral fertilizer available to the developing countries, it could contribute substantially to increasing their agricultural production. Its greater use would be especially beneficial in tropical areas, where organic matter is an essential component of soil fertility and stability.

The storage and disposal of organic waste products are not without problems, and hygienic and pollution hazards need to be taken into account. Drainage or run-off water leaving the farm may pollute sources of drinking water, and may carry with it considerable amounts of phosphate and nitrogen from manure heaps. Special care therefore needs to be taken to prevent soluble organic compounds from getting into drainage ditches and surface water. The amounts of manure or slurry spread on the land must be determined on the basis of the absorptive capacity of the soils and the nutrient requirements of the crops to be grown. With the use of sewage sludge, attention must also be paid to the content of heavy metals, which may in the long run accumulate in the soil at toxic levels.

The use of manures, compost and night soil as a plant nutrient can be combined with the production of biogas (methane).[43/] The process reduces the loss of organic matter through decomposition and stops nitrogen losses. At the same time, it provides gas for cooking and reduces the requirements for fuelwood, the collection of which is, as already noted, a serious threat to forest resources in some parts of the developing world.

Symbiotic nitrogen fixation

In the context of the possible pollution of the environment as a result of excessive applications of fertilizers, it is necessary to consider the possibilities of economizing in their use. One way of doing this is by making fuller use of the fixation of atmospheric nitrogen by nodulated legumes through their symbiosis with the Rhizobium bacteria. This is an important source of soil nitrogen, which in some cases may increase the nitrogen available for subsequent crops. It should in fact be considered as a significant component of the natural resources for food and agricultural production. Its more effective use gains even greater relevance in the light of the high price of mineral fertilizers in relation to the purchasing power of small farmers in developing countries, and the present dependence of the manufacture of nitrogen fertilizers on feedstocks deriving from fossil fuels.

[43/] For a fuller discussion, see: FAO, The State of Food and Agriculture 1976, op. cit., p. 88, 92.

Results obtained in certain countries have shown that the potential of tropical legumes for fixing nitrogen is as high, or almost as high as that of temperate ones.[44/] In the temperate zones, pastures of white clover and ryegrass can fix the equivalent of 250 to 400 kg/ha of nitrogen per year. In the tropics, several legume and grass mixtures are known to fix 200 to 250 kg/ha per year, and some much higher figures have also been obtained. An indication of the potential is the wide variety of pulse crops grown in the developing countries, especially in Asia, as a major source of protein. The total harvested area of such crops in the developing countries (including the Asian centrally planned economies) is estimated as about 60 million ha in 1976.[45/]

The greater and more effective use of symbiotic nitrogen fixation in developing countries is now being given increased attention. In cooperation with UNEP, FAO has made an assessment of the potential in several countries of Africa and Latin America.[46/]

Inoculation with Rhizobium bacteria can be used to improve the nodulation of traditionally grown crops, or when a new crop is introduced into an area where the specific Rhizobium is not present. Lotononis, Desmodium and Centrosema are examples of forage legumes which require a specific strain, in the absence of which they will obtain their nitrogen from the soil. Soybeans are a similar example among crops of major economic significance. They are indigenous to the Far East, and when they are grown in other parts of the world it is essential to inoculate them with their specific Rhizobium strain. It is estimated that the fixation of atmospheric nitrogen by well-nodulated soybeans can reach from 25% to more than 50% of the total needs of the crop.[47/] The persistence of the specific Rhizobium in old fields is limited, so that it is necessary to inoculate soybeans at sowing. This can be carried out at low cost, and is now a common practice.

Field studies have also shown that, within certain Rhizobium strains, there are some which are more efficient than others. By the use of plant breeding, it is therefore possible to obtain a more efficient symbiosis. In general, however, there is still insufficient knowledge and practical experience of how to make better use of symbiotic nitrogen fixation. For example, in some countries 150 kg/ha of nitrogen fertilizer is used to grow lucerne, while in others with similar ecological conditions none is required. Nevertheless, it is essential to consider the inoculation of legumes with their appropriate Rhizobium strain as one of the inputs required for higher production.

The possibility of extending nitrogen fixation to non-legume crops is also promising.[48/] Some cowpea strains of Rhizobium can form abundant nitrogen-fixing nodules on the small non-legume bush Trema cannabina. Casuarina trees, which are very useful in semi-arid areas as shelter belts to prevent soil erosion, have been found to have nitrogen fixing non-legume nodules formed by actinomycetes. In Senegal, casuarina trees can fix up to 60 kg/ha of nitrogen per year.

The role of blue-green algae in biological nitrogen fixation is also hopeful. It is estimated that algae associated with a water fern (Azolla) in rice paddies contribute more

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44/ Shaw and Bryan (eds.), Tropical Pasture Research, Commonwealth Agricultural Bureau Bulletin, 1976.

45/ FAO Production Yearbook 1976, op. cit., p. 116

46/ FAO/UNEP, Development of a Programme Promoting the Use of Organic Materials as Fertilizers, Rome, 1976.

47/ J.R. Jardini - Freize, in FAO/UNEP Report on Biological Nitrogen Fixation (in the press).

48/ P.J. Dart, Recent Developments in the Field of Biological Nitrogen Fixation, CGIAR, TAC, 14th Meeting, Hyderabad, 14 - 18 October 1976.

fixed nitrogen than the root system of the plant, which fixes around 0.05 kg/ha per day.[49] Nitrogen balance studies at the International Rice Research Institute (IRRI) and elsewhere indicate that an average of 60 kg/ha of nitrogen can be taken up by a rice crop, other than that from fertilizers.

PESTICIDE USE

Pests[50] represent one of the major constraints on agricultural production. Until effective means of control, in the form of synthetic organic pesticides, became generally available, cultural controls such as crop rotation and field clearing were almost the only means of reducing their impact. Some of the changes associated with the intensification of production, such as greater reliance on monoculture, increased fertilizer use, improved water management, multiple cropping, the use of a smaller number of crop varieties, and reduced tillage, in fact create conditions which can increase the danger of pest attack. For example, in the United States, notwithstanding the considerable increase in the use of plant protection measures, the total losses from pests appear to have increased in the last 30 years both in absolute terms and as a proportion of the value of the crop.

Various attempts have been made to estimate the magnitude of the losses caused by pests, but the results are still far from satisfactory. FAO has recently established a programme to collect further information. In general, the losses due to pest attack are put at between 20 and 40% on a worldwide basis. In developing countries, where pesticides are only lightly used and other methods of control as yet poorly developed, the losses are probably still higher.

Chemical pest control

Over the past three decades, pesticides have made very substantial contributions to the great expansion in agricultural production and productivity. Particularly in developing countries, where their use is so far quite small, requirements are likely to continue to increase for many years to come. Replies from 38 developing countries to a questionnaire sent out by FAO indicated a total 1973 consumption of 162,000 metric tons.[51] This represented an increase of 23% a year since 1971, while the future increases in these countries were estimated at about 10% a year, this lower figure resulting mainly from increased costs. In many developing countries herbicides are barely used at present, and their use is expected to increase more rapidly than for any other class of pesticide. Moreover, only a very small part of the estimated 20% of total world consumption of pesticides that is accounted for by the developing countries is used for food crops.

Notwithstanding the considerable efforts being made to optimize pesticide use through integration with biological and cultural controls, the continued need for an expanding use of pesticides must be recognized. This was the conclusion of the FAO *Ad Hoc* Government Consultation on Pesticides in Agriculture and Public Health, held in 1975. It specifically recommended that further attention should be paid to raising efficiency in methods of distribution and use, to providing training and generally raising competence in monitoring the presence of residues, and to monitoring and evaluating the importance of environmental impacts of uses in developing countries.[52]

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[49] Idem, *Biological Nitrogen Fixation*, CGIAR, TAC, 8th Meeting, Washington, D.C. 24 July - 2 August 1974.

[50] Including weeds, insects, mites, rodents, birds, nematodes, bacteria, fungi, viruses, and other plant pathogens.

[51] *Pesticide Requirements in Developing Countries, Summary of Replies to 1975 FAO Questionnaire*, Ad Hoc Government Consultation on Pesticides in Agriculture and Public Health, Doc. AGP:PEST/PH/75/B44, 1975.

[52] FAO, *Report of the Ad Hoc Government Consultation on Pesticides in Agriculture and Public Health, 7 - 11 April 1975*, Doc. AGP:1975/M/3, Rome, 1975.

Efforts are being made to implement these recommendations through various components of the FAO Pesticides Programme. A number of countries are being assisted in the establishment and administration of schemes for the registration and official control of the introduction and use of pesticides. Training courses in safe and efficient use are organized. Official laboratories are being assisted to raise their competence in the detection and measurement of residues in food and other substrates. The statutory groups of experts that provide advice on official control of pesticides, on the occurrence of residues in foods, on impacts on the environment, and on the development of resistance of pests to pesticides have recently been reconstituted.

It must be recognized that over-dependence on pesticides, particularly in some developed countries with intensive agricultural systems, has led to considerable problems, including the development of pest strains resistant to the chemicals used for their control, the destruction of natural enemies of past species, the expansion of populations of species not previously regarded as pests, the occurrence of unwanted residues, and other undesirable environmental effects. But the knowledge that has become available from studies of these effects now provides a much sounder basis for planning for the future.

The experience of the last 30 years has led to the re-shaping of concepts of pest control. Greater emphasis is now being placed on the study of the complex made up by the crop, the pest, and the natural enemies of the pest, and on crop management strategies that minimize dependence on chemicals, using them to supplement cultural and biological methods rather than to supplant them. There is also greater emphasis on the introduction of pest resistant crop strains, and on possible new departures such as the use of attractants, repellents and hormones as pest control agents. This broad multidisciplinary approach to practical pest control has come to be referred to as integrated pest management.

Integrated pest management

It has become evident that nature can play a much more important role in the control of pests than was previously thought. Even with pests causing regular damage to crops, parasites and predators can cause considerable mortality. Such a situation should be fully exploited, and should not be disturbed, for example by the indiscriminate use of pesticides.

In the developing world, where food crops are almost entirely produced on a small farm basis, there are good opportunities to promote the principles of integrated pest management from the beginning. These principles include the application of pesticides only when needed and in a way which avoids killing natural enemies (ecological selectivity); the development and introduction of pest-resistant crop varieties; the adoption of suitable agricultural practices; biological control, such as the use in China and various Latin American countries of artificially multiplied parasites to control certain caterpillars; and the correct forecasting of pest development.

Integrated pest management has been successfully introduced, for example, in certain cotton-growing areas, including Nicaragua, Peru and the United States. This experience has demonstrated that the amount of pesticides needed to control cotton pests effectively may be reduced by more than 50%.53/ In Central America the sole reliance on pesticides, with up to 40 applications per season, created serious environmental contamination, including the development of pesticide-resistant plant pests and vectors of malaria, and the elimination of natural predators.

A Panel of Experts on Integrated Pest Control was established by FAO in 1966, and the FAO/UNEP Cooperative Global Programme for the Development and Application of

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53/ L.A. Carruth and L. Moore, Cotton scouting and pesticide use in eastern Arizona, Journal of Economic Entomology, 66, 1973, p. 187 - 190.

Integrated Pest Control in Agriculture was initiated in 1975. This programme provides for the setting up of inter-country programmes on major crops, including demonstration and training, applied research, and assistance in the implementation of knowledge at the farm level.

New regulations adopted in many countries will already reduce, to a large extent, the shortcomings of pesticides use as they were revealed in the past. Moreover, the gradual adoption of integrated pest management practices will further optimize the use of pesticides. It must, however, be recognized that it will still need considerable efforts to permit the full and effective use of these new approaches.

Because of their effectiveness and easy use, pesticides will remain essential elements in crop protection programmes for the foreseeable future. Continued efforts must be made to ensure that they supplement rather than supplant good crop and pest management practices, and that they are distributed and used with maximum efficiency and safety to man and the environment.

POLLUTION PROBLEMS OF FOREST INDUSTRIES

The pulp and paper industry has had a bad reputation in public opinion as a gross polluter, especially of rivers and lakes into which untreated effluent was discharged. In recent years, the environmental issue has become widely recognized and the industry has been under heavy pressure by environmentalists and legislators to reduce the harmful effects of both liquid effluent and atmospheric discharges. In some countries very strict laws have been passed and are rigidly enforced. In developing countries, the tendency is to undertake some form of environmental impact assessment and to plan control measures case by case.

The processes used to reduce liquid effluent pollutants include the settling of solid matters as a first step, followed by biological treatment and, as a last step in some cases, colour removal. Internal measures, such as the reduction of water consumption through its efficient recirculation and the recovery of pulp and liquor spills, are very effective means of reducing effluent pollution, and this method is employed by most new mills. New bleaching processes also reduce the worst source of pollution. Atmospheric pollutants, particulate matters and obnoxious gases are treated by scrubbing devices, chemical treatment, and burning.

As a result of all these measures, pollution from the pulp and paper industry has been drastically reduced. After the completion of the abatement programmes now being carried out in at least the main producing countries, the point will soon be reached where the pulp and paper industry is no longer a major hazard to the environment. However, this will not be achieved without considerable cost. The installation of pollution abatement systems is a heavy financial burden for the industry, and cannot be accomplished without affecting product prices. In some cases it has not been financially possible to eliminate effluent discharge from old mills, and this has caused the closure of the operation and consequently unemployment. It must therefore be understood that there is a price to pay for a clean environment.

Among the mechanical forest industries, fibreboard manufacturing is technologically the closest to the pulp and paper industry. If adequate purification facilities are not installed, wet process fibreboard mills are often a source of considerable water pollution. Good progress is reported from various parts of the world in the implementation of the most efficient and economical ways of water pollution abatement in fibreboard industries. In addition, during the last few years several mills have achieved the complete closure of the "white water" system. This requires additional expenditure on investment and operation, and also affects certain characteristics of the final products. It has, however, paid off handsomely in densely populated areas with scarce water resources, where fibreboard mills were faced with the possibility of closing down if they continued to pollute.

Another means adopted by fibreboard industries for coping with water pollution has been the application of the dry method of manufacture, which does not require water for the forming of the fibre mat and therefore causes no water pollution problems. There are, however, disadvantages in using this system. Synthetic adhesives are needed as an additive in the manufacturing process, and there is considerable air pollution.

Other mechanical wood product industries (sawmilling, and plywood and particle board manufacture) do not produce substantial amounts of toxic wastes, but their disposal of organic waste (bark and wood particles) can create pollution problems in waterways, due to oxygen depletion. However, these problems can be alleviated by the use of the organic wastes. Residues from sawmilling can be used for pulp and board manufacture, or as fuel.

FOOD AND FEED CONTAMINATION

In recent years the intensification of production, the increased use of storage, and the centralized processing, distribution and handling of food and feed have created greater potential hazards of chemical or biological contamination. Chemical contamination is more characteristic of the present industrial era. Biological contamination is mainly due to underdevelopment and poverty, and can often become endemic.

Chemical contamination of food and feed may originate from industrial activity, industrial wastes, chemicals and pesticides used in agriculture which find their way into the food chain, and toxic metals such as lead, cadmium or mercury arising also from pressing, packaging, seed dressings or accumulations. Biological contamination is caused by pathogenic micro-organisms such as salmonella, enterotoxin producing bacteria, and various parasites and fungi.

Greater awareness of the problems of food and feed contamination and its contribution to health hazards and economic losses has emerged during recent years. Spectacular and tragic accidents, like Minamata and Niigate in Japan, resulting in aquatic pollution with mercury and its resultant uptake and accumulation by edible fish, have helped to highlight these problems. Other examples have included the findings that "itai-itai" disease in Japan was the result of environmental contamination provoking high levels of cadmium in food over long periods of time; the accidental use of mercury treated seed wheat as human and animal feed in Iraq; and the accidental admixture of polybrominated biphenols with cattlefeed and the consequent loss of thousands of cows and over 1½ million chickens, pigs and sheep in the United States. It is estimated that 71% of the outbreaks of food-borne diseases in the United States in 1969 resulted from contamination of food by pathogenic micro-organisms.[54] Food is a good indicator of the quality of the environment in which it is produced, and has often been the trigger which has set natural resources protection measures in motion.

As a result of a series of such mishaps, added to a more general awareness of the problems of the environment and of the need for the protection of food, systematic food contamination monitoring now exists in many industrialized countries. The results of such monitoring have already proved useful, for example in the United Kingdom with lead in infant foods, in Sweden with mercury in fish, and in Canada, the United States and a number of European countries with pesticide control.

In the developing countries the main problems of food contamination are found in the sub-humid and humid tropical zones, where they arise mainly from contaminants of biological origin, such as parasitic infections in livestock, enterotoxin producing staphylococci, coliform bacteria, and the group of enterobacteriaceae. The lack of scientific knowledge and of an appropriate infrastructure for food control has also been responsible for several large-scale accidents of food poisoning in these zones. A major problem that has been increasingly recognized during the past two decades is that temperature and atmospheric humidity favour the development of fungi and the production of toxic metabolites (mycotoxins).

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[54] W.H. Booker Jr. et al., Food-borne disease surveillance, Washington State, American Journal of Public Health, 64(7), 1974, p. 854-859.

The classic example of the effects of a mycotoxin is the ergot poisoning that, during the Middle Ages and sporadically since that time, has resulted from the consumption of cereal grains infected with the parasitic fungus Claviceps purpurea. In 1942-47 there were numerous deaths in certain communities in the U.S.S.R. associated with the fungi present in overwintered mouldy grain. Nevertheless, the hazards from these and other moulds continued to be largely ignored. Then, in the early 1960s, over 100,000 turkeys died after eating groundnut cake contaminated with the mould Aspergillus flavus. Epidemiological data support the hypothesis of a causal role for aflatoxin, the toxic metabolite of this mould, in the aetiology of primary liver cancer in Africa and southeast Asia, where the disease is common. Toxicity data are scarce for man, but a recent report from India indicated that in 1976 over 100 people died after consuming mouldy maize for a period of about two months, with an average daily consumption of aflatoxin of about 6 mg.[55] Although the mycotoxin problem is more acute in the tropical and subtropical countries, it is not confined to those areas. Other mycotoxins such as ochratoxin, zearalenone and the trichothecene toxins have been demonstrated to be responsible for adverse effects in animals and man on a worldwide basis. Outbreaks of mycotoxicoses in farm animals have been reported in many countries of the temperate zone.

In the developing countries the economic losses caused by the contamination of food and feed can often be of great significance. The introduction of tolerance limits for aflatoxin by many importing countries has led to reduced export earnings for crops such as groundnuts, and sometimes the total loss of the import market. Millions of tons of food and feed are lost every year because they are not sufficiently protected against insects, rodents, and microbiological and man-made chemical pollutants. These losses are especially important in developing countries, because they add to the extent of malnutrition.

Problems relating to fish and fishery products cover a large number of natural and artificial contaminants. Chemical contamination has affected some fisheries, where accumulation through the food chain has caused levels in certain products to exceed the standards adopted by some countries. Trace metals may also be a problem.

Measures for the control of food contamination through environmental pollution consist of monitoring and surveillance, and the strengthening of food control activities. Several developing countries are seeking to start such programmes. The FAO/WHO Codex Alimentarius Commission has been developing international food standards both to protect the consumer and to facilitate trade, and these standards contain provisions for maximum levels or residues of certain important contaminants. FAO, WHO and UNEP are also developing a Joint International Food and Animal Feed Contamination Monitoring Programme. The major objectives of this programme are to determine global trends of food contamination; population groups that may be at high risk; the geographical spread of certain specific highly toxic contaminants; the total intake of such substances via food; the total exposure to a contaminant through air, water and food; the extent and trends in the contamination of food by biological agents; and to provide information to those responsible for the development of international food standards containing a contaminant component.

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[55] K.A.V.R. Krishnamachari, R.V. Blat, V. Nagarejan and T.S.B. Trilak, Investigations into an outbreak of hepatitis in parts of western India, Indian Journal of Medical Research, 63, 1975, p. 1036 - 1049.

SELECTED ENVIRONMENTAL PROBLEMS OF SPECIFIC ECOLOGICAL ZONES

In the developed countries the gradual transition from traditional systems of agriculture to modern intensive methods of production took more than a century. In the developing countries the pace of change has had to be far more rapid, largely because of the very backward situation from which it started, and the unprecedented population growth of the last 30 years or so.

The difficulties of the developing countries have been aggravated by the inaccessibility to small farmers of modern inputs such as fertilizers and pesticides,by outmoded rural institutional structures, and by the lack of trained manpower to provide essential government services to the millions of scattered small farmers. The insufficiency of the data base for the assessment of the state of natural resources and of present and potential damage to the environment, together with the general lack of adequate land use planning with due attention to environmental considerations have proved much more serious in view of the very rapid changes that are inevitably taking place. Moreover, the ecological balance appears generally to be more fragile in the tropical and sub-tropical zones, where most of the developing countries are situated.

Thus, as will be apparent from the earlier review of the state of natural resources, tremendous strains have been placed on some of these resources, and the formerly well-adapted traditional patterns of agricultural production in the developing countries have been dislocated. A number of the environmental problems that have arisen from population pressure and the consequent utilization of natural resources beyond their carrying capacity are characteristic of specific ecological zones. A discussion of some of these problems by ecological zone has the advantage of making it possible to get away from the somewhat piecemeal approach that had to be adopted in reviewing the state of the main natural resources, and to look simultaneously at the whole complex of natural resources and the impact of man's activities upon them. Out of the many such problems only three can be briefly reviewed here: shifting cultivation, desertification, and problems of land utilization in the highlands.

SHIFTING CULTIVATION IN THE HUMID AND SUB-HUMID TROPICS

The term shifting cultivation is used to describe a traditional system of tropical agriculture which relies on natural fallows for the maintenance of soil fertility. In its simplest form, farmers clear the land, burn the cleared vegetation, and cultivate plots in forest, bush or grassland until crop yields fall below the subsistence level. When the original area is considered to have recovered its fertility, they return to repeat the process, until once again the land is apparently exhausted. The period of fallow, which varies according to the climate and the inherent fertility of the land, is from 8 to 12 years in tropical rain forest, up to as much as 20 or 30 years in drier areas.

Problems arise with shifting cultivation when, because of population growth beyond the level which the system can support, cropping is intensified by reducing the length of the fallow. This usually happens when the population density reaches about 30 to 50 persons per km^2, although the figure varies considerably according to local conditions. At higher population densities, the natural cycle of regeneration is broken, and rapid soil degradation sets in. Yields become lower, and the community often suffers from severe food shortage or even starvation.

Some years ago it was estimated that over 200 million people, thinly scattered over 36 million km^2 of the tropics, obtained the bulk of their food from shifting cultivation.56/ Besides causing soil degradation, shifting cultivation also results in the destruction of

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56/ P.H. Nye and D.J. Greenland, The Soil Under Shifting Cultivation, Commonwealth Bureau of Soils, Technical Communication No. 51, Farnham Royal, Commonwealth Agricultural Bureau, 1960.

large areas of forest. It has been estimated that in Latin America between 5 and 10 million hectares are felled annually, while in the Far East there are about 24.5 million shifting cultivators, who annually fell about 8.5 million hectares of forest. In Africa, it is estimated that the original area of closed tropical forest south of the Sahara has shrunk by at least 100 million hectares because of shifting cultivation. Almost two thirds of the land under shifting cultivation is in upland forest, where very serious soil erosion follows whenever the fallow period is considerably shortened.

The problems of changing from shifting cultivation to more permanent cropping are complex and difficult to solve. The cultivators involved are trapped within a system where the rising population demands more intensive production than the soil is capable of without major improvements. Inputs such as fertilizers and better seed, and improvements such as crop rotations, mixed farming and soil conservation measures are required, but they are generally beyond the economic means of the poor farmers. Their major difficulties concern the maintenance of soil fertility, the provision of an adequate supply of plant nutrients, and the prevention of soil degradation when the natural fallow cycle is reduced or eliminated.

There are many proposals on how to approach the problem of shifting cultivation, ranging from the opinion that, from the environmental point of view, nothing should be done, to the other extreme of the complete replacement of shifting cultivation by continuous forms of land use in order to meet the increasing demand for food. In between these two extremes, various proposals and practices aim at a more or less gradual improvement of the productivity of the present system.

Experiments have been carried out, using mainly mineral fertilizers but also different types of organic material, to shorten the fallow period gradually. They indicate that appropriate farming systems, including good soil management practices, mixed cropping, the use of mineral fertilizers and the conservation of organic materials, can not only maintain the yield levels obtained with the usual fallowing practices but can considerably surpass them. This points to extending the cropping periods and eventually the possibility of replacing the fallow period completely. If, for economic and other reasons, this is not envisaged immediately, the efficiency of the fallow period could be increased by substituting the natural fallow by cover crops, part of which can be used economically. Another possibility is the introduction of semi-permanent cultivation, which consists essentially of short fallows, with some use of short-term grass fallows for cattle grazing when feasible. The rapid growth of population in many areas of West Africa and South America will enforce changes of this kind from shifting cultivation to continuous cultivation. Especially under high rainfall conditions, such changes have to include advanced soil management practices, including the use of organic and mineral fertilizers and appropriate cropping systems.

The problems of replacing shifting cultivation by more permanent cultivation are being studied in many parts of the world. More research is required to find suitable solutions for the various ecological conditions which are also socially and economically acceptable.

DESERTIFICATION

The Sahelian drought of the early 1970s, and its tragic effect on the people of the region drew,world attention to the chronic problems of human survival and development on the desert margins. Desertification is a problem on the margins of all the hot deserts of the world, and occurs on all continents. It may be triggered by various combinations of causes. It leads to lower biological productivity, with consequent reductions in the plant biomass, in livestock carrying capacity, in crop yields, and in human activity.

Desertification does not apply to the fringes of the sandy deserts only. It refers to all surfaces which, for various reasons such as overgrazing, the onset of salinity or alkalinity, or the cultivation of unsuitable areas, lose their protective vegetative cover and show the characteristics of a desert. It includes many extensive regions where

Table 3-28. Area already affected and likely to be affected by desertification, by continent

	Existing extreme desert	Degree of desertification hazards			Total	Share of total land area
		Very high	High	Moderate		
	thousand km²					%
Africa	6,178	1,725	4,911	3,741	16,555	55
North and central America	33	163	1,313	2,854	4,363	19
South America	200	414	1,261	1,602	3,478	20
Asia	1,581	790	7,253	5,608	15,232	34
Australia	-	308	1,722	3,712	5,742	75
Europe	-	49	-	190	238	2
TOTAL	7,992	3,449	16,460	17,707	45,608	35

Source: FAO, UNESCO, WMO, *op. cit.*

good soil cover existed a short time ago and where now only extremely shallow soil or perhaps no soil at all remains over the bedrock.

The inherent vulnerability of the ecosystem to desertification is determined by its present climate, terrain, soil and vegetation conditions. This inherent vulnerability is inseparable from human influence. Population and livestock density are important factors, as well as the intense pressure of cultivation associated with mechanization and the submarginal expansion of cropland agriculture. The risk of degradation by desertification is therefore a function of both the inherent vulnerability of the region and the human or animal pressures on its resources. It is greatest in arid and semi-arid zones, but is also occuring in sub-humid regions.

Although the phenomenon of desertification has been recognized for many years as a threat of great magnitude to the environment, and in particular to the welfare of people living on the desert margins, no quantitative assessment of its extent was made until the United Nations Conference on Desertification was held in Nairobi from 29 August to 9 September 1977. Within the framework of the conference, a study of desertification on a global basis, including a Desertification Map of the World, has now been published.57/ This map is reproduced in Figure 3-3. A more detailed desertification map (1 : 5 million) of Africa north of the Equator has also been prepared.

The Desertification Map of the World includes areas subject to sand movement, stony and rocky surfaces subject to stripping by blowing or washing (e.g., the reg or seria of the Sahara, and the Gibber Plain of Australia), areas subject to soil stripping and accelerated gully erosion, and areas subject to salinization and alkalinization. For human and animal population pressure, limits of 7 inhabitants per km² and one animal unit per 5 ha were chosen as critical for the arid zone, and 20 inhabitants per km² and one animal unit per ha for the semi-arid zone.

The desertification hazards are classified as very high, high, or moderate, according to the rapidity with which desertification is likely to take place if existing conditions do not change. The areas in each of these categories, together with the existing area of extreme desert, are quantified by continent in Table 3-28. The total area already

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57/ FAO, UNESCO, WMO, *Explanatory Note and Desertification Map of the World*, United Nations Conference on Desertification, Nairobi, 29 August - 9 September 1977, A/CONF.74/2.

Figure 3-3. Desertification map of the world

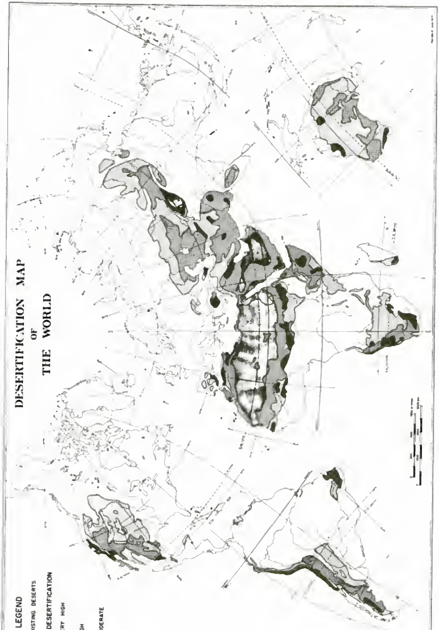

Table 3-29. Area already affected and likely to be affected by desertification, by bioclimatic zone

	Bioclimatic zone[1]							
	Hyper-arid	Arid	Semi-arid	Sub-humid	Hyper-arid	Arid	Semi-arid	Sub-humid
	.... thousand km²			....	...... % of total land area			
Existing extreme desert	7,992	-	-	-	100	-	-	-
Degree of desertification hazards								
Very high	-	1,110	2,181	159	-	6	12	1
High	-	13,440	2,440	580	-	77	14	4
Moderate	-	2,105	12,452	3,173	-	12	69	23
TOTAL	7,992	16,655	17,073	3,912	100	95	95	28

Source: FAO, UNESCO, WMO. op. cit.

1/ Defined according to climatic aridity, based on the ratio of precipitation to evapotranspiration: hyper-arid less than 0.03, arid 0.03 to 0.20, semi-arid 0.20 to 0.50 and sub-humid 0.50 to 0.75.

affected or likely to be affected by desertification is more than a third of the world's total land area. The area classified as likely to be affected is about ten times as large as the existing area of extreme desert, although in only a very small proportion are the hazards categorized as "very high".

The same data are shown by bioclimatic zone in Table 3-29. As might be expected, the degree of desertification hazards in the more arid zones is particularly alarming. As much as 95% of the total land area in the arid and semi-arid zones is subject to the risk of desertification, with most of it classified as at high risk in the arid zone. However, it is significant that desertification is not confined to the driest areas, and that the hazards reach large proportions even in the sub-humid zones.

Desertification is one aspect of the widespread deterioration of ecosystems under the combined pressures of adverse climate and agricultural exploitation. It is basically a problem of the misuse of land, in that the activities pursued in certain areas are inappropriate, either in degree or in kind, for the resources of these areas. Particularly in pastoral areas, much of the problem results from the customs, value systems and attitudes of the people concerning grazing lands and livestock, together with the lack of government mechanisms for effective control. Such attitudes and activities are either based on ignorant or calculated attempts to maximize short-term gain at the expense of long-term productivity, or perhaps more often are motivated by population pressure and lack of socio-economic development which leaves no other choice. The problem is of such magnitude and consequence that its dangers cannot be ignored.

LAND UTILIZATION PROBLEMS IN HIGHLAND ZONES

Some of the environmental problems of temperate and tropical highlands are similar. Tropical highlands in general constitute a fragile ecosystem, and are often overpopulated. However, in temperate highlands depopulation has sometimes caused their neglect.

The drastic results of forest clearing even on gentle slopes in vast parts of the tropics have already been referred to, but the effects of clear felling in steep mountain areas can be far more severe. The environment often deteriorates more quickly, and the erosion damage may be irreversible if bedrock is exposed. This problem often arises when population pressure causes extensive clear felling in the attempt to enlarge the agricultural area.

The three major mountain ranges of the developing world which are of greatest concern are the Himalayas, the Andes and the East African Highlands. A recent UNESCO expert panel expressed grave concern because of the widespread degradation in these areas.[58/] There has been a very large increase in the last decade in the destruction of forest cover, soil erosion, flood damage and silting.

As a result of population pressure, the Himalayan forests have been very quickly cleared, in places up to 2,000 m, even on steep slopes. In the rainy season, huge landslides occur. Sheets of scree debris (consisting of soil and stones) over two kilometres wide have been observed, giving unmistakable evidence of the widespread destruction taking place.

The problems of the highlands of the Andes and East Africa are similar, and in places just as serious as those of the Himalayas. They vary according to population density. Most of the Andean countries have a very high population growth, resulting in an almost unbearable pressure on the highlands. However, in some parts of the Andes it is because of migration from the hills, and the consequent inability to maintain old soil erosion control terraces and dams, that the environment is deteriorating. In some of the more heavily populated highland areas of East Africa soil erosion is very serious.

Any solution to the problem of highland deterioration must first cope with the basic cause of overpopulation, through planned emigration and the provision of alternative employment, for example by promoting international tourism. Other possibilities which need further attention are the development of erosion control measures at high altitudes in tropical areas, the provision of better roads, increased output from the better land, and the revegetation of marginal lands.

Cultural and political factors are of primary concern. Another important aspect is the adverse effects on the lowlands which result from highland deterioration. Flood damage and silting are greatly increased, and migration from the hills can result in the reckless settlement of lowland areas, leading to excessive demands on their productive capacity.

LEGISLATIVE ASPECTS

Environmental problems are not only caused by natural or technological factors. They are often generated and usually aggravated by socio-economic factors as well. Outmoded patterns of land and water use are often closely tied to the underlying legal structure of ownership and rights of use. In this sense, there may be many legal constraints on the more rational use of natural resources. At the same time legislative measures themselves constitute a powerful tool in arriving at the better use of natural resources and the avoidance of environmental problems.

Such problems as land degradation and desertification stem partly from the legal structure. The excessive intensification of production, for instance, may in part result from the excessive fragmentation of holdings, owing to existing laws regarding land

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[58/] UNESCO, Impact of Human Activities on Mountain and Tundra Ecosystems tenure and succession. Overgrazing may be partly caused by traditional rights of land use, which are insufficiently adapted to changing economic and demographic circumstances. The mutual legal claims of upstream and downstream water users, whether based on contiguity or acquired rights of use, may prevent the optimal development of shared water resources. Similarly, the historical legal regime of the oceans raised the danger of the overexploitation of common marine resources.

Outdated legal structures may thus act as constraints on the rational management of resources. This is, however, not necessarily so. Many countries have begun to rediscover the advantages of adapting long-existing legal instruments for the new requirements of resource conservation and environmental protection. Examples are the discharge permits required pursuant to the 1899 United States Refuse Act, or the remedies for neighbourhood nuisances (*troubles de voisinage*) available under 19th century European civil codes, both of which have been turned into useful instruments of pollution control today.

The very multitude and diversity of laws applicable to natural resources and environmental matters, and the ensuing risk of overlapping or contradictory regulations and competences, have been recognized as a problem in most countries. While the need for coordination and administrative reorganization is urgent, new integrated legislation should not be considered as a panacea. The effectiveness of modern environmental law depends to a large extent on sound sectoral legislation and administration for specific resources in such traditional fields as land and water law, forestry, fisheries and wildlife legislation, and health and food regulations.

One of the shortcomings of past legislation for the conservation and protection of natural resources has been its predominantly negative and punitive approach. While legal restrictions are necessary to avoid over-exploitation and interference by incompatible activities, legislation should do more than just prohibit pollution, hunting, or timber-felling. The need to combine sanctions with positive incentives to implement policy objectives, and the need to provide a legal basis for the planning and management of resource use arises both at the national and the international level. For example, the 200 miles extension of national jurisdiction over living marine resources, which is emerging from the Third United Nations Conference on the Law of the Sea, not only involves (as noted earlier) increased management responsibilities for coastal states, but also creates a need for the review and harmonization of legal regimes and institutions.

There is also a close interrelation between national and international aspects as regards the effects of legal rules on international trade. Strict environmental controls unilaterally applied to certain commodities and products in one country may seriously affect imports from other countries. In order to reconcile conflicting national laws and standards in this field, international efforts at harmonization are required, along the lines of the work already undertaken by the Joint FAO/WHO Codex Alimentarius Commission.

Since different countries share common problems of resource management and environment protection, they should also share the experience acquired in coping with these problems, and endeavour to develop mutually acceptable solutions. The international exchange of information for this purpose includes the exchange of legal data. Several United Nations Specialized Agencies have for many years disseminated information on the current legislation of their Member States in such environment-related fields as health law[59/] and renewable natural resources law.[60/] The principal aim of these information services is to bring innovative developments in national legislation to the attention of other interested countries. In 1976 FAO and UNEP initiated a joint experimental project for the cataloguing of such environmentally relevant legislative data in computerized form.

59/ WHO, *International Digest of Health Legislation*.

60/ FAO, *Food and Agricultural Legislation*.

A significant trend in both national and international law-making in this field has been the broadening scope of legal rules, from a use-oriented to a resource-oriented perspective. Some countries have attempted the comprehensive codification of all rules relating to renewable natural resources and environment protection, in a single natural resources or environment code. Others, while retaining separate legal instruments for different categories of resources, have introduced substantive reforms, with a change in emphasis from the police functions to the management functions of the law, and to new incentives for compliance; from classical nature protection to natural resources conservation; from water and air pollution controls to general anti-pollution acts; from provisions for specific dangerous chemicals, such as pesticides, to the regulation of all potentially harmful substances; and from laws protecting particular species of animals and plants, to trade controls over the primary and secondary products derived from them.

At the same time, besides re-allocating administrative competence between existing and new institutions, a growing number of countries have enacted framework legislation laying down general policies and procedures for environmental management, including citizen participation in decision-making. The regulatory systems developed for this purpose usually require either special licences or environmental impact statements for all activities involving potential environmental risks. At the international level, a combination of legal restrictions with compulsory licencing and joint technical measures has been developed, for example for the control of waste dumping in ocean and inland waters. There is also a tendency to establish (by law, and in some cases by international agreements) functional administrative units for ecological areas which are either particularly suitable for resource management (e.g., self-governing water basin authorities) or particularly endangered (e.g., nature reserves and parks).

There now are more than 40 multilateral conventions dealing with natural resource management and conservation. These have especially concerned the marine environment. While a number of these treaties are global in scope (possibly culminating in a future convention on the law of the sea), the main advances in recent years have been made at the regional level. In particular, a number of new legal instruments have been created (and existing agreements revised) for the joint management of inland water resources and ocean fisheries, and for environmental protection in special marine regions such as the Baltic, the Mediterranean and the Red Sea. Together with bilateral agreements on shared resources and trans-frontier pollution, and with the related declarations, recommendations and standard-setting activities of several international and regional organizations, these instruments may be considered as part of the growing body of international environmental law. Besides serving as secretariat for several of the institutions concerned, FAO has contributed to the development of new methodological approaches in this field by way of information exchange, legal drafting assistance, and the organization of expert meetings and intergovernmental conferences.

CONCLUSIONS

This preliminary survey of the state of natural resources and the human environment for food and agriculture brings out the wide variations that exist in the use and conservation of these resources. At the global level, the world's natural resources appear to be adequate for mankind's likely needs. However, they are unevenly distributed in relation to the population and its demands on them, and their utilization thus creates environmental problems in particular areas. These problems frequently differ in both nature and degree as between the developed and developing countries.

In the developed countries the unprecedented rise in levels of living has brought very heavy demands on natural resources from both the industrial and agricultural sectors. It has stimulated the development of highly industrialized, energy-intensive agricultural systems, in order to maximize the productivity of natural resources. This has created problems such as waste disposal, which have necessitated technical and legal measures and comprehensive planning to reduce the adverse environmental impact. Moreover, agricultural processing and service industries, like other industrial activities, have caused the pollution of land, water and air, and the contamination of food and feed.

In the developing countries, on the other hand, the major environmental concern is not so much the pollution of natural resources as their degradation or depletion. The rapid increase in the population of these countries has placed great pressure on natural resources. The consequent drive to intensify production has caused the dislocation of traditional agricultural systems, and has led to sometimes over-hasty attempts to replace them by modern agricultural systems and technologies that are not compatible with the prevailing ecological and socio-economic conditions. Many of these changes are taking place in tropical ecosystems that are more fragile than those of the temperate zone. Full scientific knowledge of the productive capacity of the natural resources in these ecosystems is still lacking.

Although the environmental problems of the developed and developing countries are thus different, their experience in overcoming them could be mutually beneficial, especially in the light of the energy crisis. There are a number of main types of action that are required at the national and regional levels, particularly in the developing countries, for the assessment of natural resources and for their rational management so that the demands on them can be met on a sustained basis.

It is necessary to reduce the knowledge gaps in the assessment of natural resources, by means of adaptive research on the introduction of new technologies in traditional agricultural systems. Multidisciplinary research is particularly required on the effects of environmental factors and technological inputs on the physical and biological productivity of tropical agricultural systems. More emphasis should be placed on the application of research findings at the field level under specific local socio-economic conditions.

A further requirement for the improved assessment of natural resources is the development of coherent networks of data on these resources. Sectoral surveys and inventories are essential, but they should increasingly be part of and compatible with a broader scheme for the full assessment of the relationships between man's activities and the state of natural resources. Local ad hoc monitoring should be undertaken whenever there is a major change in the use of a resource, and the data collected should be used to assess the environmental impact.

As regards the more rational management of natural resources, a major need is for integrated land use planning. Such planning should be comprehensive enough to link both physical and socio-economic requirements, and should aim to guide rural development programmes towards the rational management of natural resources for increased productivity. It should be dynamic and flexible, so that plans can be continuously adapted to development requirements, keeping in view not only the immediate goals but also the productive capacity of natural resources on a sustained basis. Plans should also be adapted to new technologies, and revised according to the findings of new research and surveys. A large part of the planning should be carried out at the local level, involving local communities and taking into account the diversity of the rural environment.

In view of the heavy pressure that is indiscriminately put on land resources, especially in developing countries, to meet the increasing demand for food and agricultural products, it is important to concentrate the intensification of agricultural production as far as possible in the most suitable areas. This will reduce the pressure on marginal lands which are ecologically fragile and subject to rapid degradation if they are exploited beyond their productive capacity. The more suitable areas should be developed through sound soil and water conservation and land use practices, taking account of the ecological limitations and the demands of the local population for socio-economic development.

A further requirement for more rational management is the promotion of well-adapted systems of production that integrate modern technology with the traditional systems of resource management. In many areas there is a move away from traditional uses of natural resources in agriculture. During the transition stage, many valuable components of the old systems (which usually take account of the need for the balanced use of resources) are discarded. More attention has been paid in recent years to the integration of the modern technologies required for the intensification of production with traditional production systems. It is necessary, however, to promote the exchange of information on promising new approaches based on traditional systems, and to guide and assist small farmers to a better understanding and utilization both of natural resources and human skills. Farming systems that closely associate crop and animal husbandry, and agri-silviculture and aquaculture are particularly appropriate. The aim should be to help small farmers adopt self-reliant systems which make full use of local traditional knowledge, experience and custom.

In conjunction with the application of improved technologies, it will be necessary to develop adequate rural institutions and infrastructures, including extension, credit and marketing services that are adapted to the needs of small farmers. It must be recognized that it is particularly difficult for extension and other services to train small farmers in developing countries in appropriate agricultural practices and in the safe use of new technologies. This is mainly because of the large number of people and production units involved, and the scarcity of production means and of trained personnel, but another less frequently recognized factor is the rapidity with which changes are occurring in the rural areas of the developing countries. This has a strong bearing on the degradation of natural resources. In order to prevent millions of farmers from damaging the productive capacity of the resources at their disposal, it is urgently necessary to disseminate and apply the information and experience already available, and to provide them with the means for achieving increased productivity on a sustained basis.

At the same time, it is necessary to develop a legal system to define the rights and duties of individuals or groups in relation to the utilization of natural resources in the light of their ecological limitations. The legal framework for this purpose has to be flexible enough to take account of the traditional system of regulatory power, as well as changes in the pattern of resource use. A mechanism is also required for the rational planning, implementation and monitoring of the use of natural resources from national to village level.

Education on the better management and conservation of the natural resources used in agriculture is another requirement. It should aim to make the general public aware of the ecological limitations on the potential of natural resources, of the need to utilize these resources in a rational manner, and of the rapid degradation which may occur through reckless management.

At the more technical level, education for improved resource use should provide administrators, decision-makers, extension officers and small farmers with a sound knowledge of all the operational aspects of good resource management. This should include not only the technical aspects, but also their relationship to the socio-economic environment in which they must be applied.

In addition to these general requirements for action in such fields as research, data collection and monitoring, planning, institutions and services, legal systems, and education and training, it is possible to identify a number of specific major problems on which a concerted attack is urgently required. The priority areas mentioned below are divided into measures for the more rational management of natural resources, and measures to combat the existing degradation and loss of these resources. In all cases, appropriate solutions are already available, but they have to be further developed and promoted.

In the former category concerning more rational management, mention has already been made of the need to concentrate the intensification of production on the most suitable land. More generally, the improvement of soil fertility should be pursued through the judicious combination of the efficient use of mineral fertilizers with the recycling of organic materials and the wider use of nitrogen fixing organisms. Improved genetic materials should be developed by making full use of the existing genetic variability and gene combinations in locally adapted strains. Techniques of integrated pest management should be promoted. Wherever feasible, crop and animal husbandry should be integrated, and agri-silviculture developed. High priority should be given to the rational management of grasslands in arid and semi-arid areas and of tropical forests.

With respect to the existing degradation and loss of natural resources, the highest priority attaches to the control of soil erosion, soil salinity and desertification and the conservation of fish stocks and of genetic resources. Soil erosion must be controlled and eroded land reclaimed on a watershed basis, through appropriate practices for the management and conservation of soil and water resources. Salinization should be controlled and saline soils reclaimed through proper irrigation practices and drainage systems. Desertification control requires the management of vegetation according to ecological principles, including massive programmes of reforestation. The pressure on marine fish stocks can be reduced not only by agreed international measures but also by the development and promotion of aquaculture. A further major priority is for the conservation of endangered genetic resources.

Progress in the various areas outlined above requires action at many levels, from government action at the national and international levels to action at the level of the village and the individual producer. But in the final analysis, it is only through the values held and the action taken by the producers who are actually responsible for the day-to-day use of the world's natural resources that it will be possible to use these resources in a way that is conducive to increasing production on a sustained basis.

The vast majority of the world's population, and even more of its agricultural and rural population, is concentrated in the developing countries. The concept of agricultural development in these countries is now being widened to a concept of rural development that will take account of all of the needs of their populations. This concept has to be widened still further, so as to include the rational use and conservation of natural resources so that they provide not only for the present but also for future generations.

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